Lattice Energy LLC

Many-body collective electroweak neutron production

Explains anomalous presence of CNO cycle elements

In atmospheres of some white dwarf stars

LENR CNO analogue could be commercialized for green power generation here on Earth

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President and CEO

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White dwarf star - artist's image credit: Boris Gänsicke, University of Warwick

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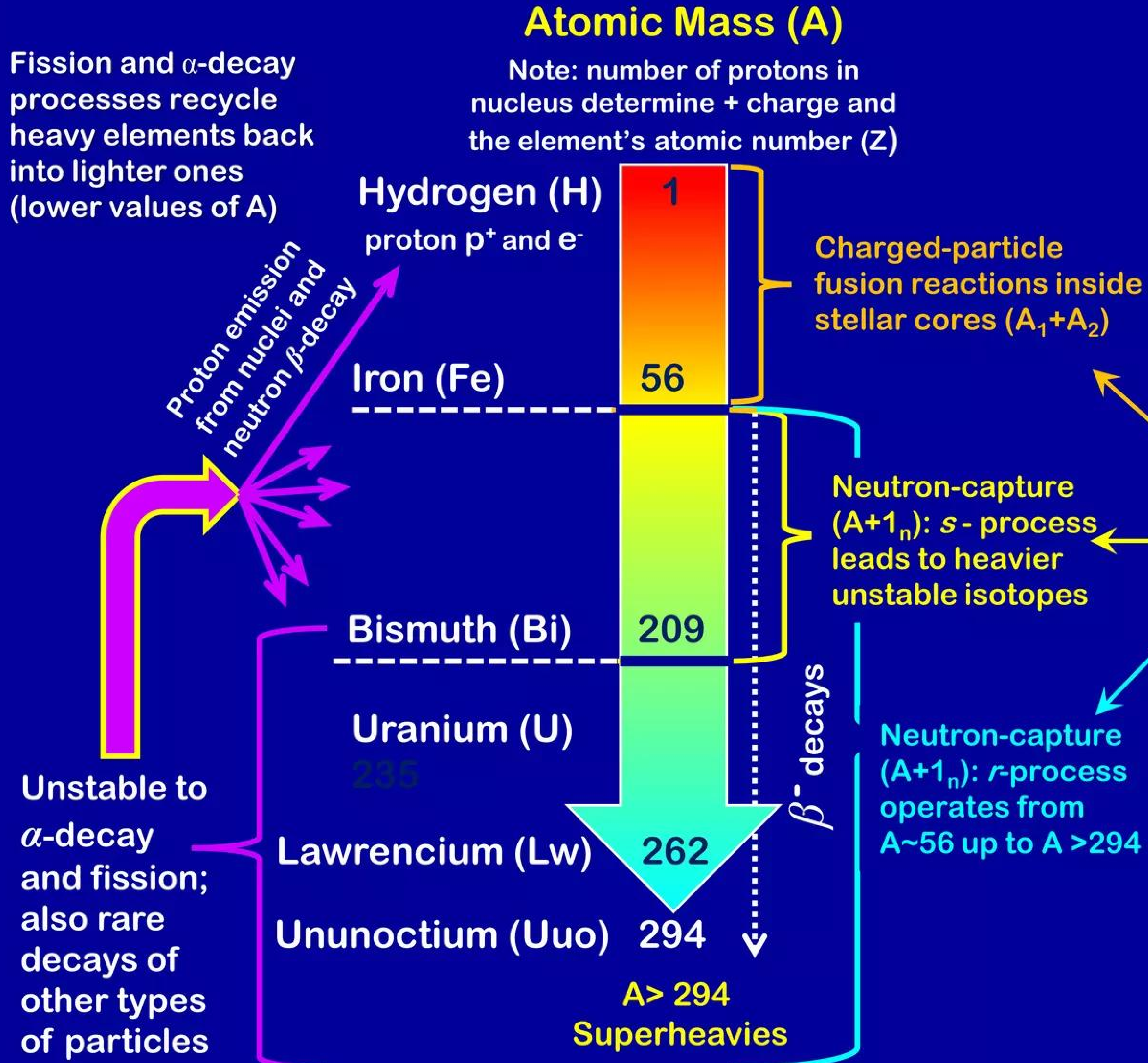
Cosmic nucleosynthetic cycle in terms of atomic mass A

Fusion up to Fe then neutron capture processes to reach superheavies

Present dominant paradigm in astrophysics and cosmology; LENRs are omitted



Different elements all have different atomic numbers (Z); a given element may have > 1 stable and unstable isotopes that differ in A (total number of neutrons + protons = A). Today, there are 118 recognized elements (heaviest is Ununoctium Uuo: Z = 118, A = 294, H.L. = ~.89 msec) and > 3,000 known stable and unstable isotopes

Charged-particle fusion reactions

s-process: thought to occur in outer envelopes of late-stage red giant stars

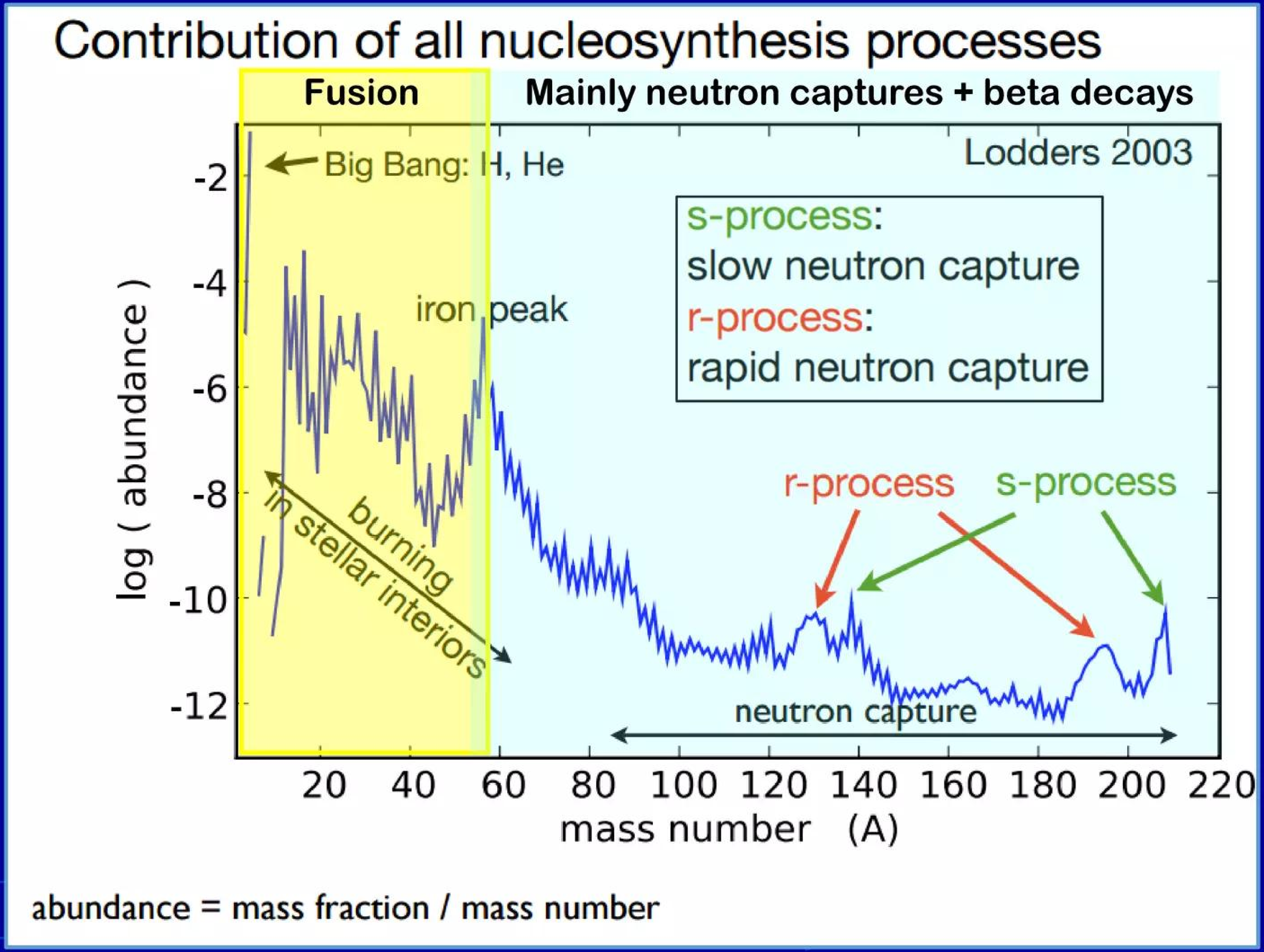
r-process: as of today, while most believe it occurs only in supernova explosions, nobody is 100% certain that idea is true

Beta-decay: unstable, neutron-rich isotopes generally decay via the beta-minus (β^-) decay process; converts a neutron (n) into a charged proton; atomic number increases by +1 which creates a stable or unstable isotope of different element; value of A = ~same

Present astrophysical paradigm about nucleosynthesis

Depending on mass, Big Bang, fusion, s-/r-processes create elements

Fusion, s-/r-processes happen in stars - little nucleosynthesis occurs elsewhere



Adapted after Lodders (2003)

Key reactions in Widom-Larsen-Srivastava theory

Many-body collective processes produce neutrons and other particles

Neutrons are captured by elements which trigger nuclear transmutation reactions

Many-body collective production of neutrons, neutrinos, and other particles:

Collective many-body processes require external input energy

$$e^{-*} + p^{+} \rightarrow n + v_e$$ Electric fields dominate

$$e^{-} + p^{+} \rightarrow lepton + X$$ Magnetic fields dominate

Electroweak particle reactions produce neutrons (n) and neutrinos (v_e)

Transmutation of elements and nucleosynthesis outside of stellar cores:

Neutron capture-driven LENR transmutation reactions

$$n + (Z, A) \rightarrow (Z, A+1)$$ Neutron capture

$$(Z, A+1) \rightarrow (Z + 1, A+1) + e_{\beta}^{-} + \overline{v}_e$$ Beta-minus decay

Unstable neutron-rich products of neutron captures will undergo beta$^-$ decay

Create heavier stable isotopes or heavier elements along rows of Periodic Table

W-L-S theory spans vast range of length-scales and energies

E-fields in condensed matter vs. B-field particle acceleration in plasmas

Short-range collective electric field effects dominate

Longer-range collective magnetic field effects begin to dominate

Long-range collective magnetic field effects dominate

local electric fields — Low - medium electric and/or ion currents

Regime: ultralow energy neutron reactions (LENRs) in condensed matter

$e^* + p^+ \rightarrow$ 1 neutron + neutrino or $e^* + d^+ \rightarrow$ 2 neutrons + neutrino

Neutron production, capture, release energy, and transmutation products

- Microorganisms – biological transmutations by certain types of earthly bacteria & fungi
- Pressure gradients across membranes – e.g., Iwamura, Li, & Arata-Zhang - gas phase
- Current-driven P&F-type chemical cells - liquid phase; glow discharge cells - gas phase
- Laser-triggered chemical cells – e.g., Letts, Cravens, Violante, etc. - liquid or gas phase

Organized magnetic fields with plasmas — High currents: electrons and/or ions

- RF-triggered dusty plasmas - gas phase
- Current-driven dusty plasmas - gas phase
- Vacuum diodes – e.g. Proton-21, Kiev, Ukraine, Sandia NL (US) in 1970s - gas phase
- Exploding wires – e.g., Wendt & Irion, Chicago 1922; Z-pinch, Sandia NL - gas phase
- Piezoelectric and pyroelectric processes in solid-state materials – Carpinteri, Naranjo
- Magnetic flux compression generators, e.g. US (LANL), Russia
- Lightning (terrestrial, planetary, nebular), especially in dusty environments – e.g., Dwyer
- ULMN-catalyzed subcritical fission reactors (<<< nuclear waste) - reprocess old wastes

Higher fluxes of neutrons

Scales-up to very large length scales — Huge range of magnetic field strengths

Mega-scale currents

Mixed regime: high energy particle reactions and/or LENRs on dust

Magnetic effects dominate large length-scale plasmas: $e^- + p^+ \rightarrow lepton + X$

- Stars - additional nuclear reactions occur in photospheres, flares, and further out in coronas
- Dusty, hydrogen-rich nebular plasma clouds exposed to stellar photon and particle radiation
- Magnetars/active galactic nuclei: W-L mechanism can in theory create UHE TeV cosmic rays

>>>> fluxes

~0 eV Ultra low energy neutrons .... MeV neutrons ...GeV...TeVs ...EeVs

Increasing neutron and charged particle energies

Many-body collective effects span vast range of length-scales

W-L-S theory and its collective effects extend from LENRs in condensed matter regimes to environments found in high-current exploding wires, e.g., large wire inductors, as well as up to large-length-scale, magnetically dominated regimes that occur in astrophysical systems

Length Scale	Type of System	Electromagnetic Regime	Many-body Collective Phenomena	Comment
Submicron	Certain earthly bacteria and some fungi	Very high, short-range electric fields	Transmutations, high level of gamma shielding	Obtain unavailable trace elements; survive deadly gamma or X-ray radiation
Microns	Hydrogen isotopes on metallic surfaces	Very high, short-range electric fields on solid substrates	Transmutations, high level of gamma shielding, heat, some energetic particles	This regime is useful for small-scale commercial power generation
Microns to many meters	Exploding wires, planetary lightning	Dusty plasmas: mixed high-current and high local magnetic fields	Transmutations, 'leakier' gamma shielding, heat; X-rays up to 10 keV, larger energetic particle fluxes	This regime is useful for large-scale commercial power generation
Many meters to kilometers	Outer layers and atmospheres of stars (flux tubes)	Ideal and dusty plasmas: high mega-currents of electrons, protons, and ions inside large-scale, ordered magnetic structures with substantial internal electromagnetic fields	Energetic charged particles and neutrons (MeVs to EeVs), X-rays, gamma-ray bursts, and ultra-high-energy cosmic rays (TeVs to EeVs)	Provides explanation for heating of solar corona and radioactive isotopes in stellar atmospheres
Up to several AU (distance from earth to Sun)	Neutron stars and active galactic nuclei in vicinity of compact, massive objects (black holes)			Provides mechanism for creating extremely high energy particles in plasma-filled magnetic flux tubes with sufficient field strengths

Note: mass renormalization of electrons by high local E-fields not a key factor in magnetically dominated regimes on large length scales

Neutron-driven LENRs induce transmutations of elements

Widom-Larsen theory explains 100 years of anomalous experimental data

Effects were not attributed to nuclear process because hard radiation was absent

- ✓ **Widom-Larsen theory explains LENRs unique absence of hard, deadly MeV-energy neutron and gamma radiation**
- ✓ **Published in peer-reviewed physics journals: *European Physical Journal C* and *Pramana - Journal of Physics***
- ✓ **Sheds light on 100 years of anomalous experimental data. Scientists have been reporting various LENR effects in experiments since ~1900 but didn't attribute causation to nuclear processes due to the absence of hard radiation**
- ✓ **Electroweak reactions are relatively simple: heavy-mass electrons react directly with protons (hydrogen nucleus) to create neutrons and benign electron neutrino ν_e particles**
- ✓ **Safe ultra-low energy neutrons are potent nuclear particle 'matches' that induce transmutations of elements; trigger release of stored nuclear binding energy from nuclei. Very high capture cross-sections for ULM neutrons on truly vast numbers of stable and unstable isotopes makes it an ideal energy technology because fuel possibilities are enormous**

Neutrons induce nuclear reactions

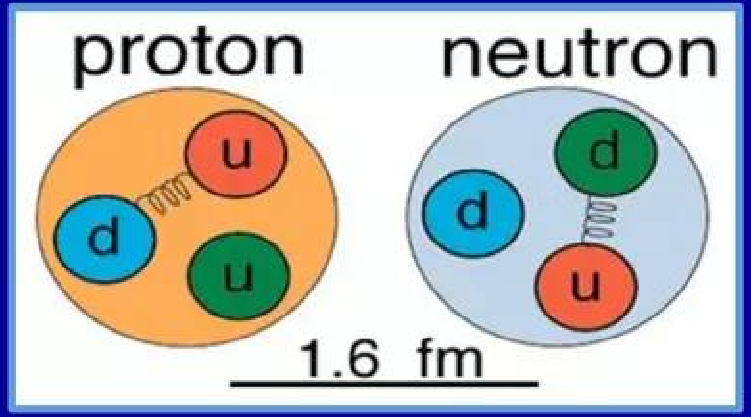
Trigger nuclear transmutations when captured by atoms of elements

Prior to W-L theory *e* + *p* reaction occurs just in supernovas

Many-body collective effects + entanglement allow it in condensed matter

W-L's first-principles rate calculations show that 10^{12} - 10^{14} cm^2/sec are achievable

- ✓ Prior to advent of the Widom-Larsen theory, astrophysicists believed that neutronization (direct e^- + p^+ reaction) *only* occurred deep in stellar cores during supernova explosions
- ✓ No "new physics" in Widom-Larsen theory: we simply integrated many-body collective and quantum mechanical effects with modern electroweak theory under the overall umbrella of the Standard Model; vast body of already-published experimental data supports theory
- ✓ Without many-body collective effects plus condensed matter quantum mechanical entanglement, electroweak reactions could *never* occur at substantial rates at moderate temperatures/pressures in chemical cells



Neutronization during supernova explosion

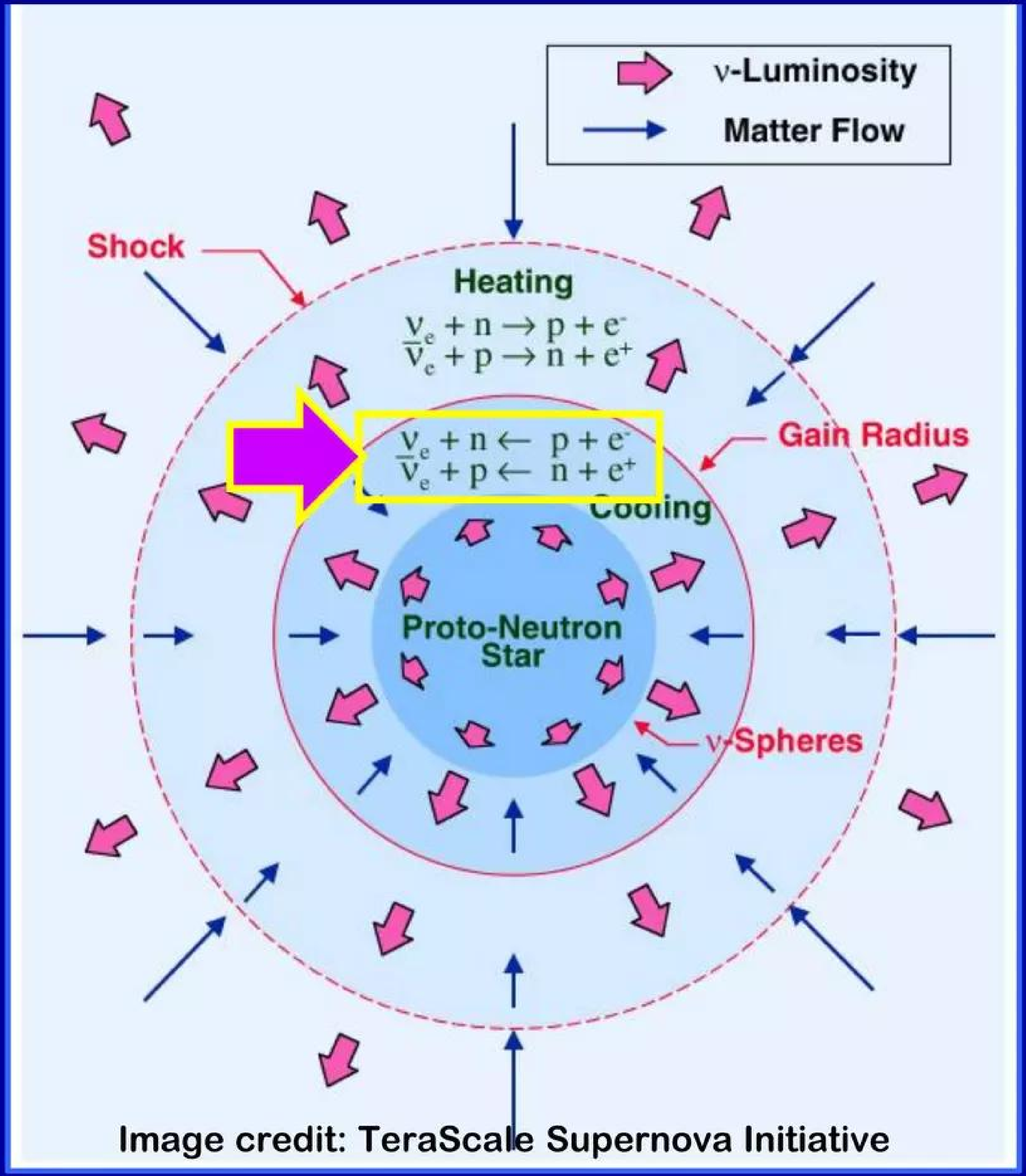


Image credit: TeraScale Supernova Initiative

Appropriate input energy is required to produce neutrons

Electron or ion currents; E-M photon fluxes; organized magnetic fields

Input energy is required to trigger LENRs: to create non-equilibrium conditions that enable nuclear-strength local E-fields which produce populations of heavy-mass $e^{-}*$ electrons that react with many-body surface patches of p^{+}, d^{+}, or t^{+} to produce neutrons via $e^{-}* + p^{+} \rightarrow 1\ n$ or $e^{-}* + d^{+} \rightarrow 2\ n$, $e^{-}* + t^{+} \rightarrow 3\ n$ (energy cost = 0.78 MeV/neutron for H; 0.39 for D; 0.26 for T); includes (can combine sources):

- ✓ **Electrical currents** - i.e., an electron 'beam' of one sort or another can serve as a source of input energy for producing neutrons via $e + p$ electroweak reaction
- ✓ **Ion currents** - passing across a surface or an interface where SP electrons reside (i.e., an ion beam that can be comprised of protons, deuterons, tritons, and/or other types of charged ions); one method used for inputting energy is an ion flux caused by imposing small pressure gradients (D^{+} permeation, Iwamura *et al.* 2002)
- ✓ **Incoherent and coherent electromagnetic (E-M) photon fluxes** - can be incoherent E-M radiation found in resonant electromagnetic cavities or emitted by stars; with proper momentum coupling, SP electrons can also be directly energized with coherent laser beams emitting photons at appropriate resonant wavelengths
- ✓ **Organized magnetic fields with cylindrical geometries** - many-body collective magnetic LENR regime with direct acceleration of particles operates at very high electron/proton currents; includes organized and so-called dusty stellar plasmas; scales-up to stellar flux tubes on stars with dimensions measured in kilometers

LENRs operate like r- and s-process in condensed matter

Electroweak $e^- + p^+$ reactions can occur in domains besides supernovae

- ✓ In our *European Physical Journal C - Particles and Fields* paper (2006) we explained how many-body collective quantum effects in condensed matter can produce ultralow energy neutrons via the electroweak $e^- + p^+$ reaction in tabletop apparatus under very modest macrophysical conditions. Results of subsequent neutron-catalyzed transmutation reactions resemble astrophysical s- and r-processes only at temperatures vastly lower than with stars
- ✓ We next analyzed and explained case of LENR transmutation products observed in high pulsed-current exploding wires with cylindrical geometries; note that collective many-body magnetic effects (B-fields) dominate therein. This case differs from condensed matter chemical cells wherein micron-scale, nuclear-strength local E-fields and local breakdown of Born-Oppenheimer are much more important
- ✓ Once one understands LENRs in magnetically dominated collective systems, lightning discharges are conceptually like a big exploding wire up in the sky. Moreover, predicted electroweak $e^- + p^+$ reactions inside solar coronal loops and flares is direct extension of the same physics principles

Widom-Larsen theory can explain LENRs on surfaces

Electromagnetic (E-M), chemical, and nuclear processes interoperate

Crucial role of surface plasmon electrons makes E-M resonances very important

- ✓ According to Widom-Larsen, chemical and nuclear processes actively coexist and sometimes may even interoperate on condensed matter surfaces
- ✓ In condensed matter systems, LENRs involve very complex interactions between surface plasmon (SP) or molecular π electrons, E-M fields, and myriad of different nanostructures that can have varied geometries, surface locations relative to each other, different-strength local E-M fields, and varied chemical or isotopic compositions
- ✓ To varying degrees, many of these complex, time-varying surface interactions are electromagnetically coupled to each other on different physical length-scales: thus, mutual E-M resonances on nanometer scales can be very important in LENR systems
- ✓ Besides optical frequencies, SP and/or π electrons in condensed matter systems may have absorption and emission bands in infrared (IR) and UV regions of spectrum
- ✓ For example, some regions on a given surface may be absorbing E-M energy locally, while others nearby can be emitting energy (e.g., as energetic electrons, photons, other charged particles, etc.). At same time, SPs can transfer energy laterally from regions of resonant absorption or capture to other regions in which energy emission or consumption is taking place: e.g., photon or electron emission and to drive LENRs
- ✓ LENRs likely occur on surfaces of some Hydrogen-rich dust grains irradiated by stars

Condensed matter LENRs occur in μ-scale surface regions

Enabled by many-body collective effects and local quantum entanglement

1. Collectively oscillating, quantum mechanically (Q-M) entangled, many-body patches of hydrogen (protons or deuterons) form spontaneously on surfaces

2. Born-Oppenheimer approximation breaks down, allowing E-M coupling between Q-M entangled surface plasmon electrons and patch protons; allows application of input energy to create nuclear-strength local electric fields > 10^{11} V/m that will increase effective masses of surface plasmon electrons in such patches

3. Heavy-mass surface plasmon electrons formed in many-body patches can react directly with electromagnetically interacting Hydrogen isotopes; process creates neutrons and neutrinos via many-body collective electroweak reactions, namely:

$$e^{-*}_{sp} + p^{+} \rightarrow n + \nu_e \qquad e^{-*}_{sp} + d^{+} \rightarrow 2n + \nu_e \qquad e^{-*}_{sp} + t^{+} \rightarrow 3n + \nu_e$$

4. Neutrons collectively created in patch have ultra-low kinetic energies and are all absorbed locally by atoms - few neutrons escape into environment; locally produced gammas converted directly into safe infrared photons by unreacted heavy electrons (Lattice patent US# 7,893,414 B2) - no hard gamma emissions

5. Transmutation of elements: formation of μ -scale craters at active sites begins

6. **Neutron production rates in condensed matter systems can hit 10^{12} - 10^{14} cm^2/sec**

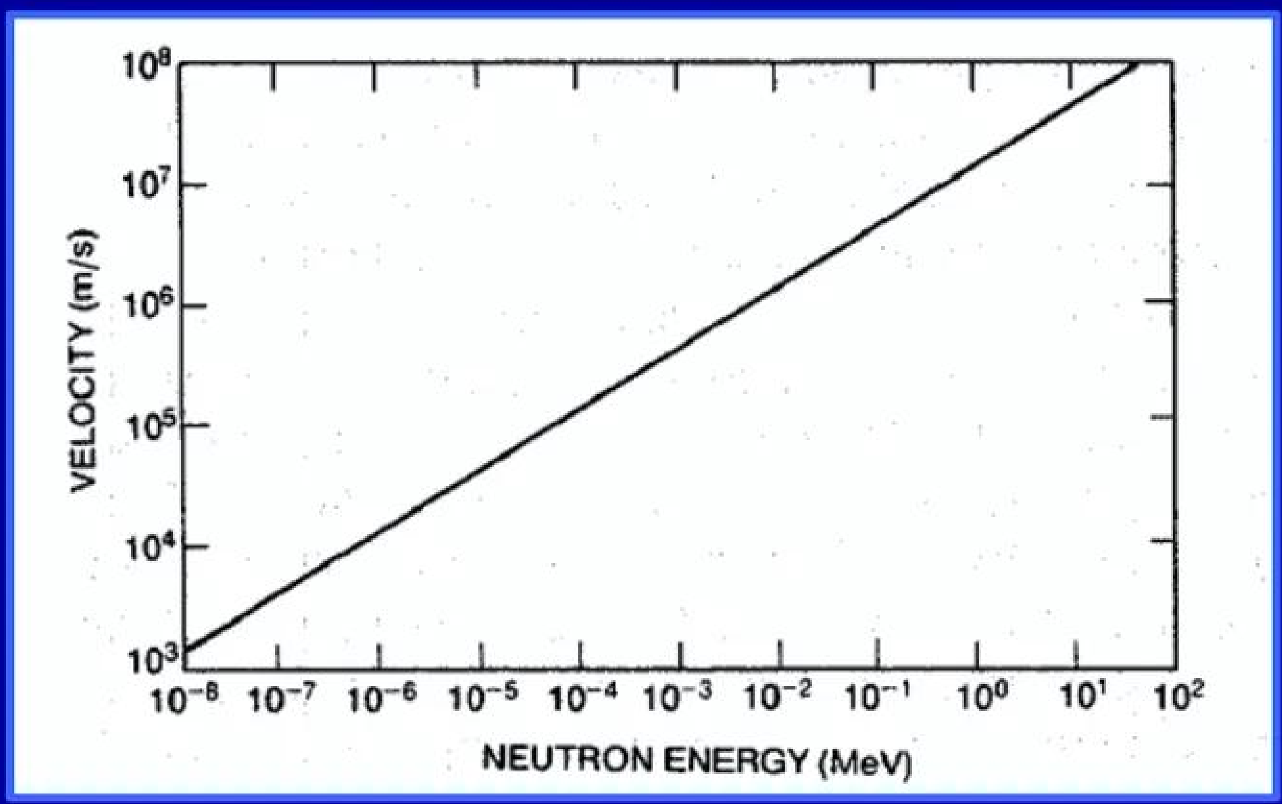
Collectively produced neutrons have ultra low momentum

Capture cross-sections vastly higher than for neutrons at thermal energy

Neutron capture rates on dust grain surfaces can be much higher than in plasmas

- ✓ If capture cross-sections of ULM neutrons could be measured, they would be far, far beyond the left-side margins of graph over to right
- ✓ All isotopes shown in right chart would have much larger capture cross-sections for ULM neutrons

Velocity (m/sec) vs. Neutron energy



Source: P. Rinard

Neutron capture cross-sections vs. neutron energy

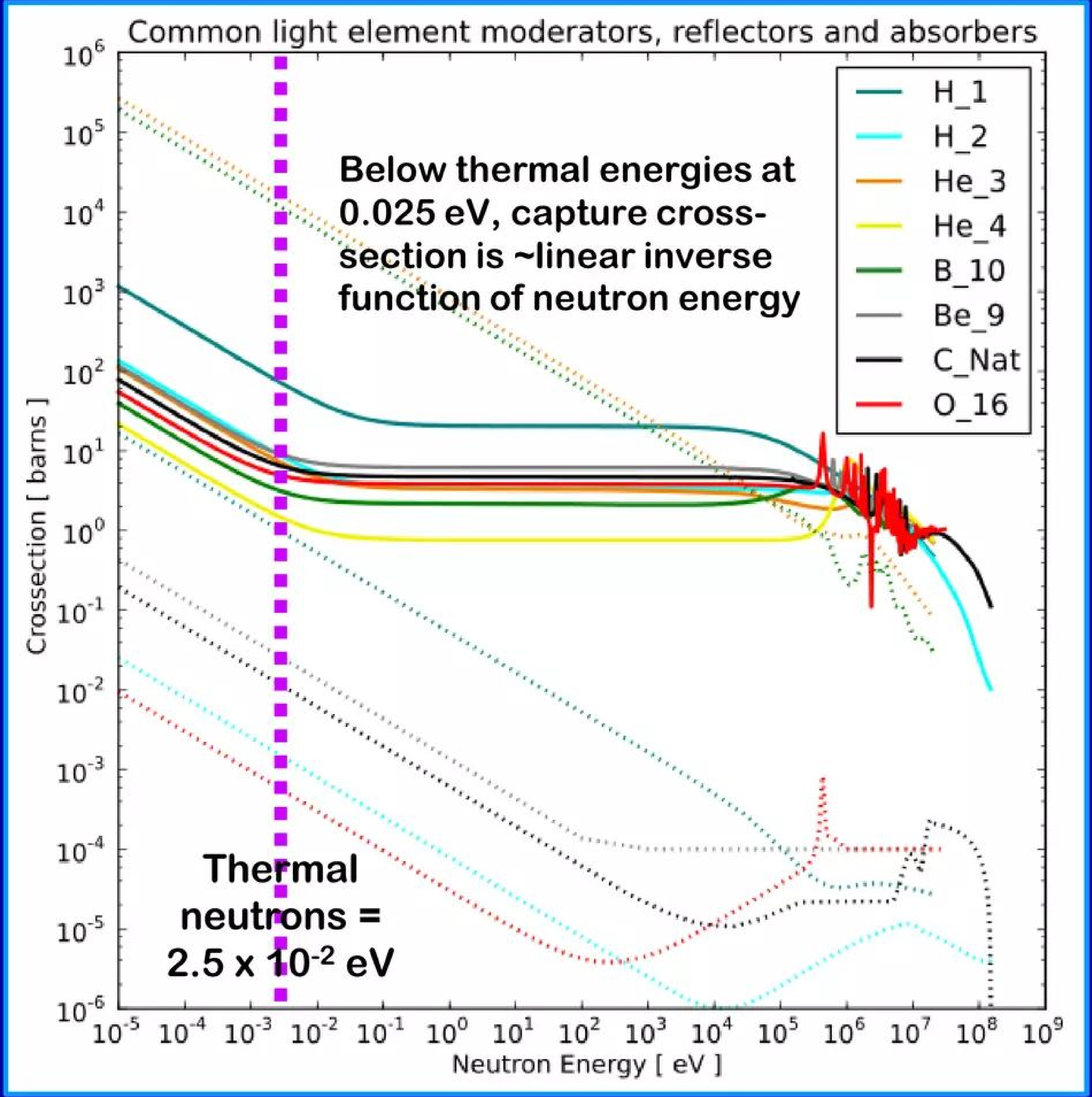


Figure adapted from source: Wikipedia

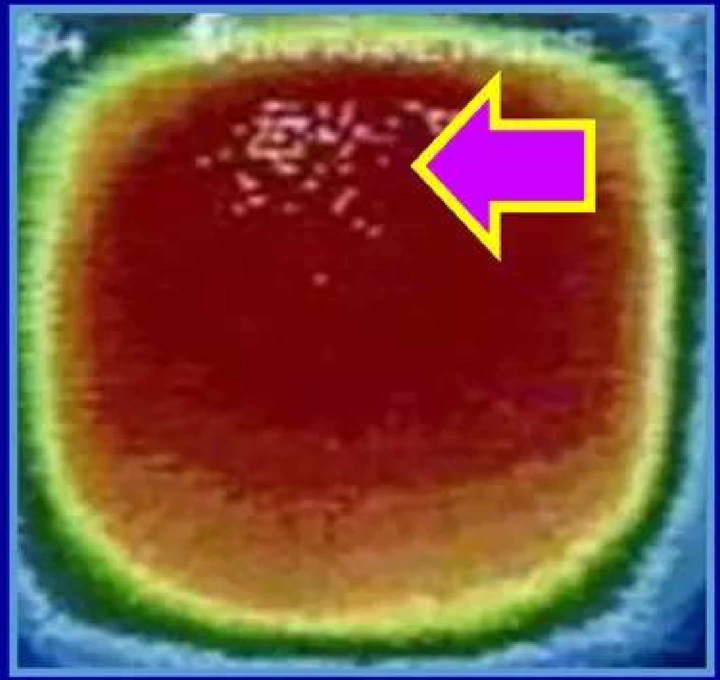
Widom-Larsen provides explanation for LENR-active sites

Size of these active sites ranges from 2 nanometers up to ~100+ microns

Active sites have limited lifetimes before being destroyed by fast nuclear heating

- ✓ Per W-L theory, LENRs occur in localized micron-scale LENR-active sites on ~planar surfaces, at certain types of interfaces, or on curved surfaces of natural or manmade nanoparticles
- ✓ Tiny LENR-active sites live for less than ~300 - 400 nanoseconds before being destroyed by intense heat; local peak temps range from 4,000 - 6,000º C; LENR-active sites spontaneously reform under right conditions in well-engineered LENR thermal devices
- ✓ Microscopic 100-micron LENR hotspot can release as much as several Watts of heat in < 400 nanoseconds; create crater-like features on surfaces that are visible in SEM images and show evidence for flash-boiling of both precious & refractory metals
- ✓ Peak local LENR power density in microscopic LENR-active sites can hit > 1.0 x 10^{21} Joules/sec·m^3 during brief lifetimes
- ✓ Control macroscopic-scale temperatures in LENR systems by tightly regulating total input energy and/or total area/volumetric densities of LENR-active sites present in the reaction chambers

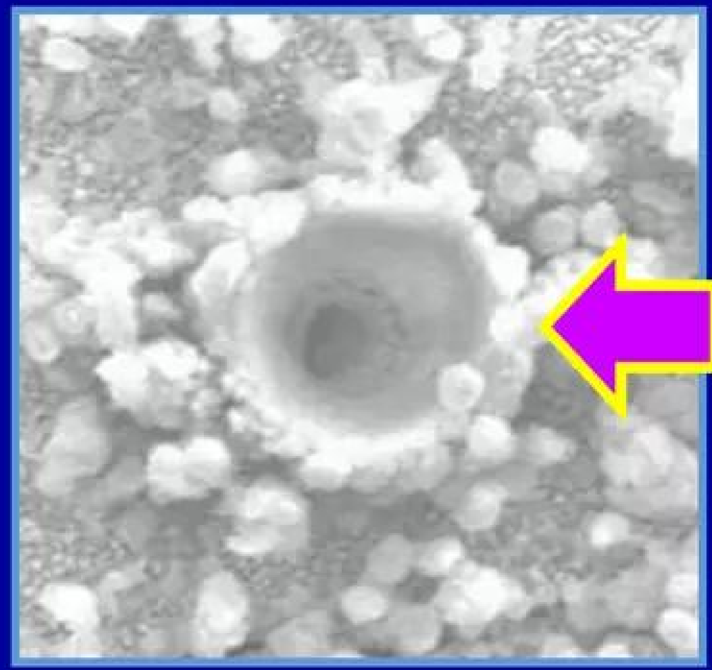
LENR hotspots on Palladium
Infrared video of LENR hotspots



Credit: P. Boss, U.S. Navy

http://www.youtube.com/watch?v=OUVmOQXBS68

100 μ LENR crater in Palladium
Boiling point 2,963°C



Credit: P. Boss, U.S. Navy

Release of nuclear binding energy produces infrared heat

Several different mechanisms produce clean heat in LENR-active sites

Widom-Larsen explains what generates excess heat in condensed matter LENRs

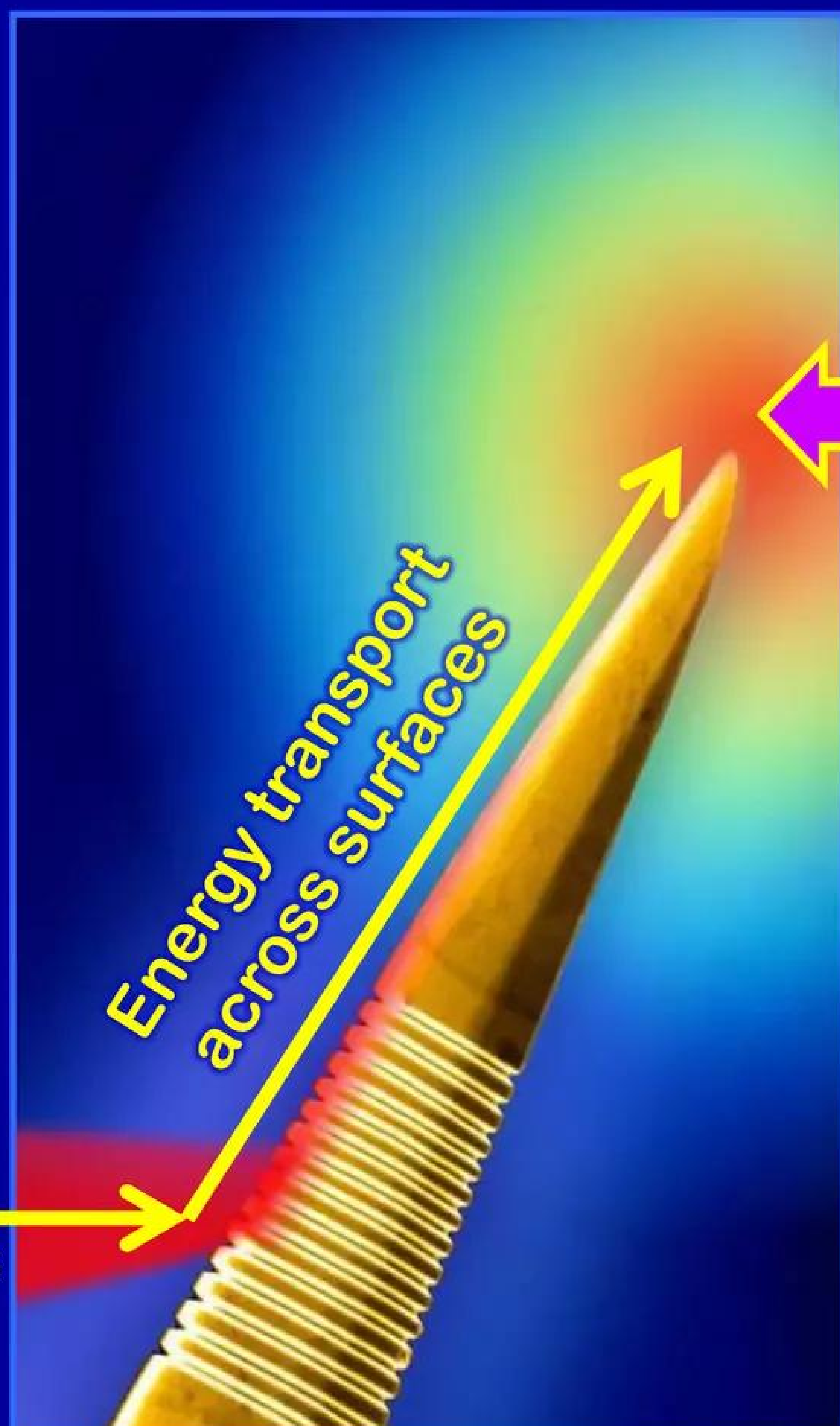
- ✓ Conceptually, LENR neutrons act like catalytic 'matches' that are used to 'light the logs' of target fuel nuclei. A neutron-catalyzed LENR transmutation network operates to release nuclear binding energy that has been stored and locked away in nuclei 'fuel logs' since they were originally produced at multi-million degrees in fiery nucleosynthetic processes of long-dead stars, many billions of years ago
- ✓ LENR transmutation networks can produce copious heat that comes mainly from:
  - Direct conversion of gamma photons (γ) into infrared photons (IR) by heavy electrons; e.g., γ from neutron captures or β and other types of decays. IR is then scattered and absorbed by local matter, increasing its temperature (heat)
  - Nuclear decays of unstable neutron-rich isotopes that emit energetic particles (e.g., betas, alphas, protons, etc.); these particles then transfer their kinetic energy by scattering on local matter, which increases its temperature (heat)
- ✓ Neutrino particles from weak interactions do not contribute to any production of excess heat; they will essentially bleed-off a small portion of released nuclear binding energy outward into space; unavoidable neutrino emissions are part of the energetic cost of obtaining energy releases in LENR networks from β^- decays

Surface plasmons readily mediate input energy to LENRs

SP electrons can absorb, transport, concentrate, and store input energy

Many types of naturally configured nanoparticulates can capture E-M input energy

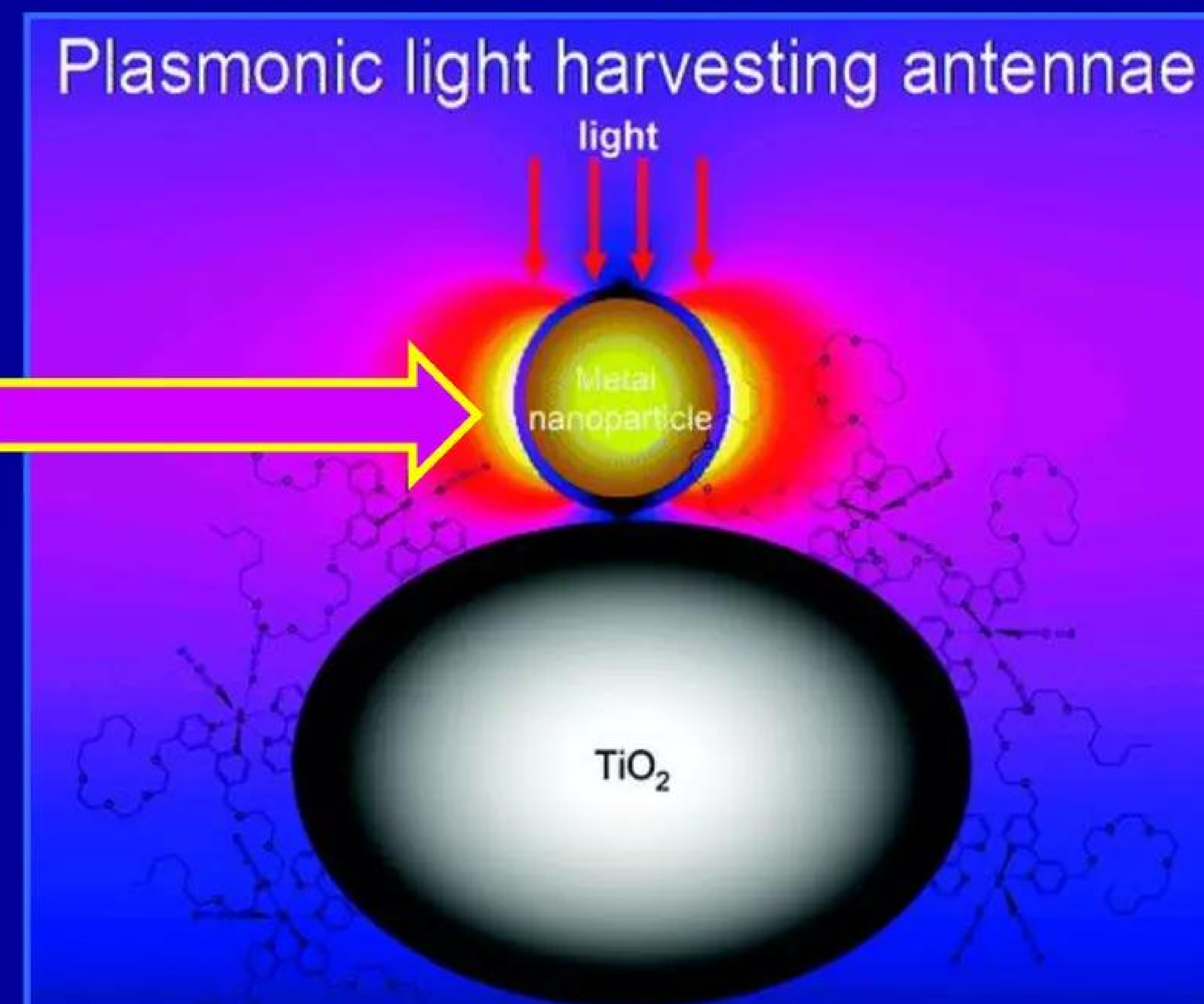
Sharp tips can exhibit “lightning rod effect” with very large increases in local electric fields



E-M photons

Regions of very high E-M fields

Source of image just below is the Wiesner Group at Cornell University; shows target nanoparticle on TiO_2



http://people.ccmr.cornell.edu/~uli/res_optics.htm

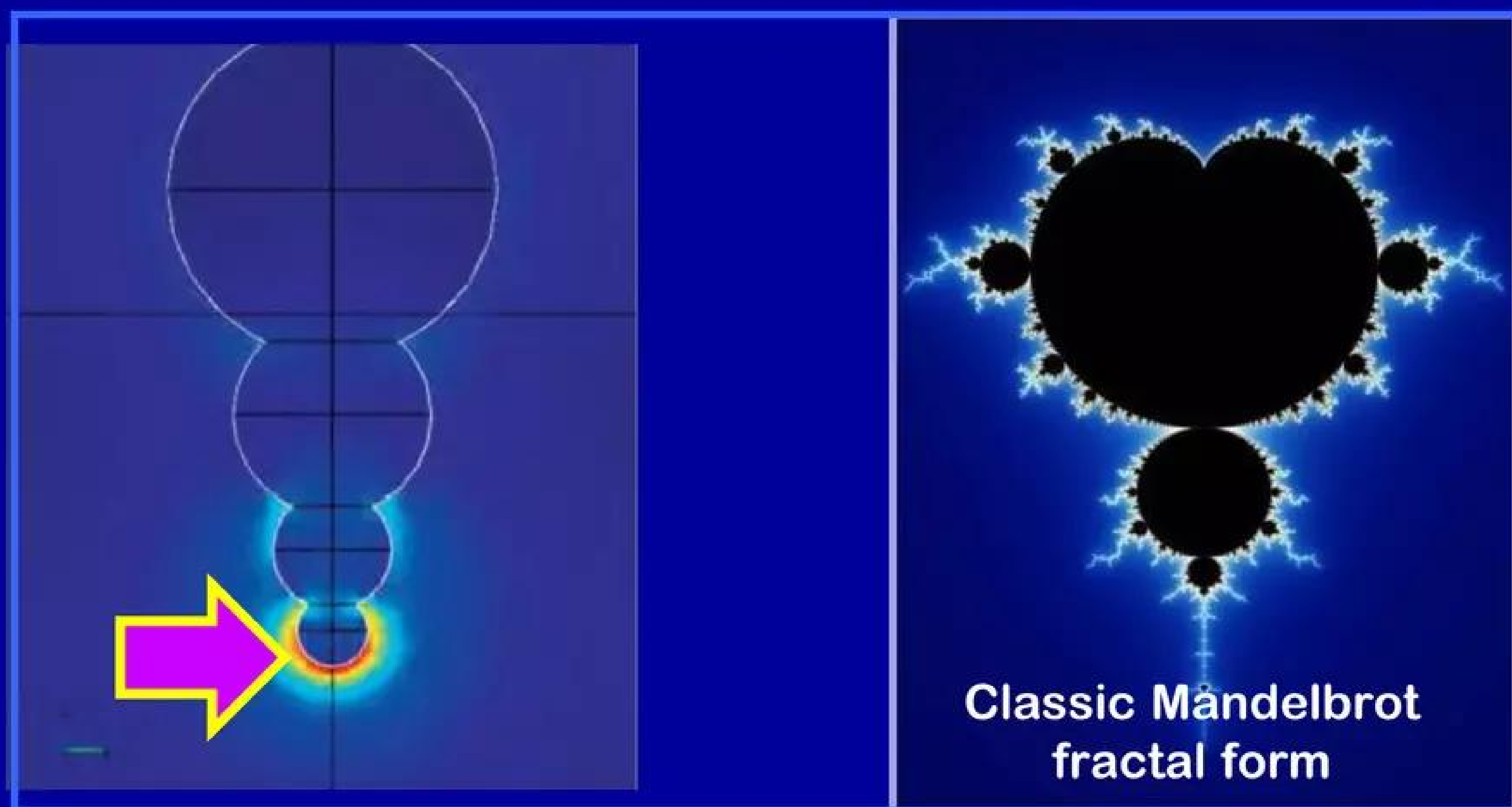
See: “Plasmonic dye-sensitized solar cells using core-shell metal-insulator nanoparticles," M. Brown *et al.*, *Nano Letters* 11 (2) pp. 438 - 445 (2011)

http://pubs.acs.org/doi/abs/10.1021/nl1031106

Nanoparticle shape/proximity can boost local electric fields

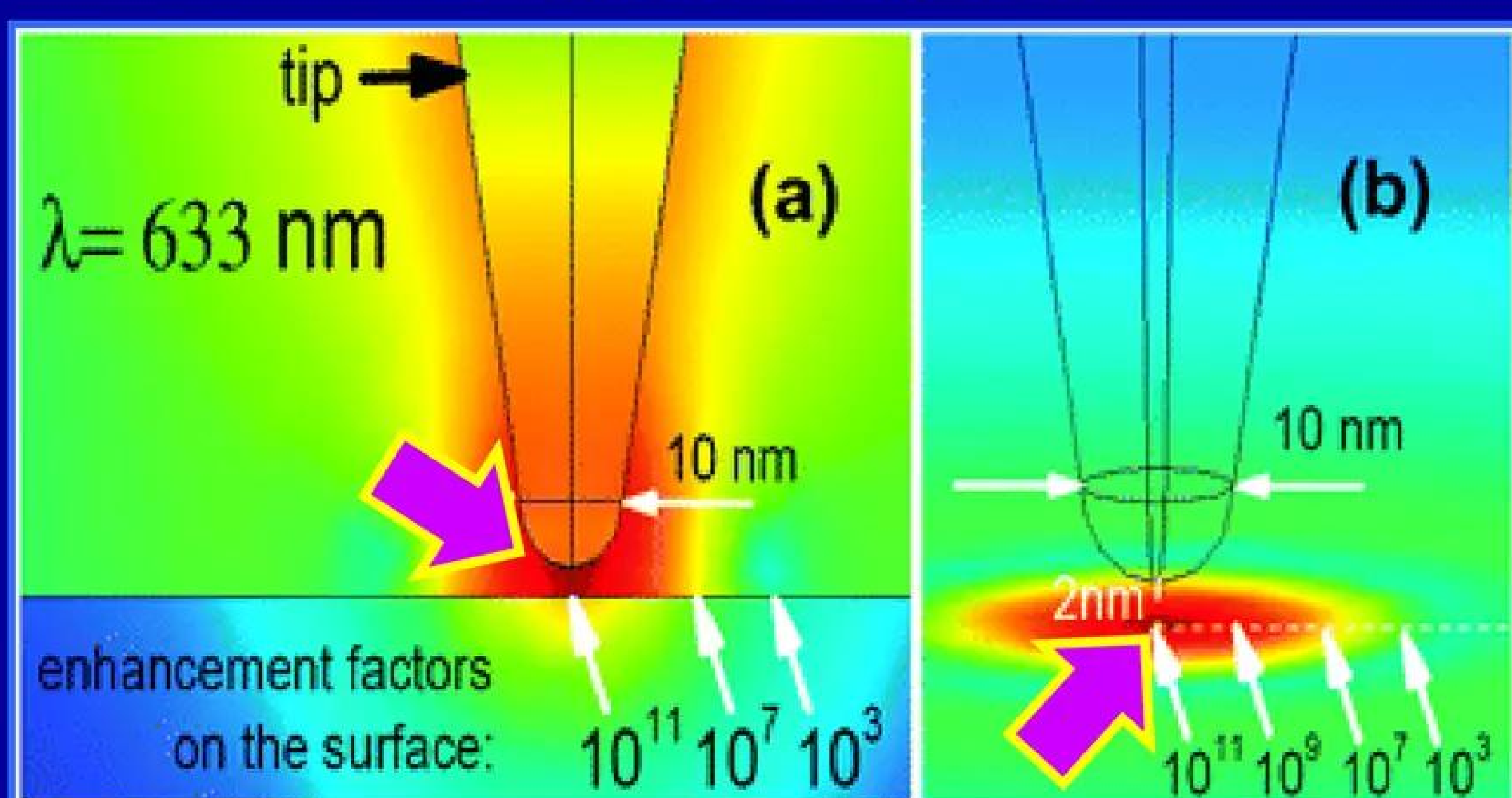
SP electrons can absorb, transport, concentrate, and store input energy

Nanoscale electric fields can be increased by multiples that may reach 10^{11} times

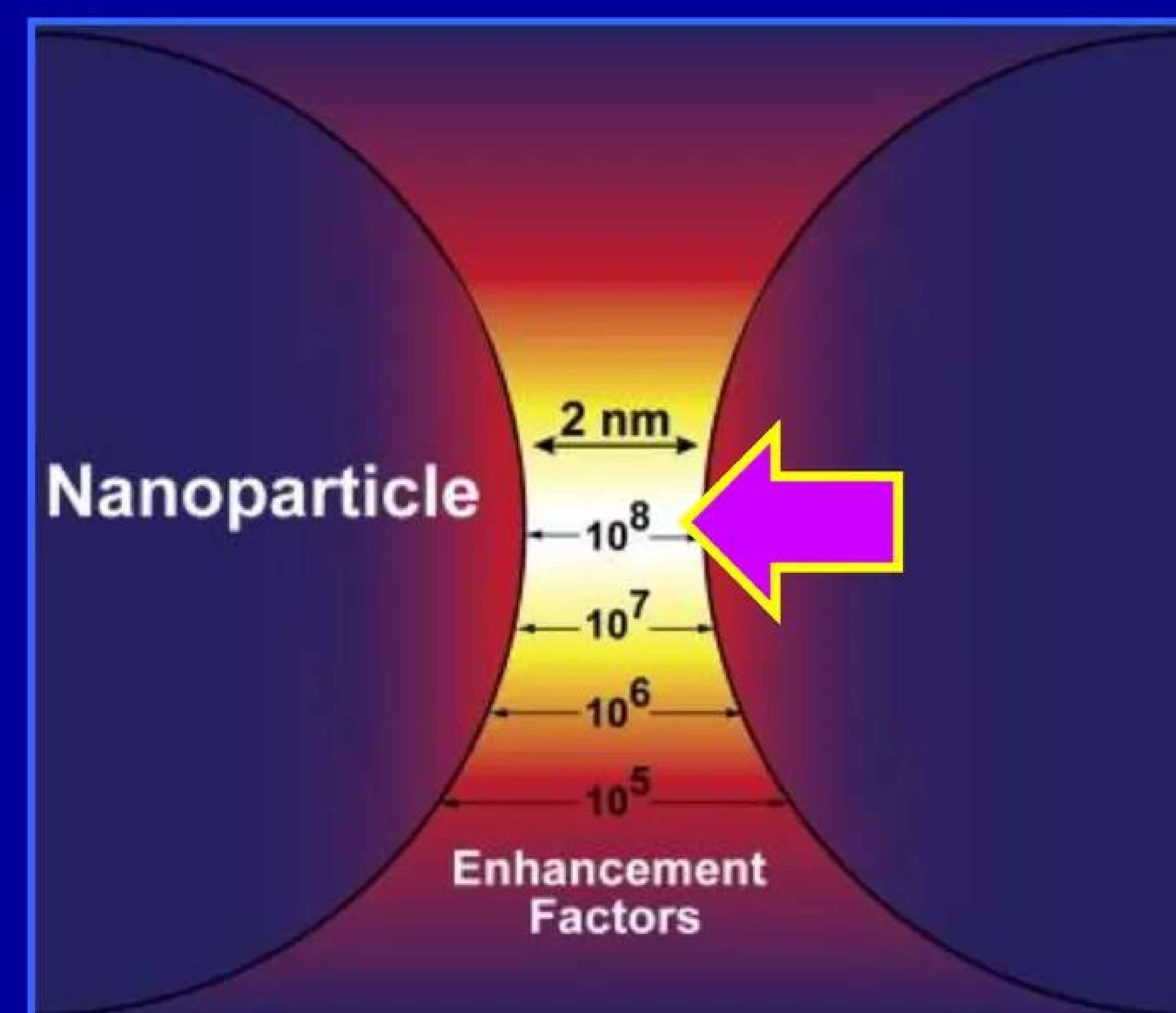


Sharp tips can exhibit the so-called “lightning rod effect” in terms of huge local enhancement of electric field strengths

Electric field enhancement at nano-antenna tip from R. Kappeler *et al.* (2007)



E-M field strength enhancement as a function of interparticle spacing

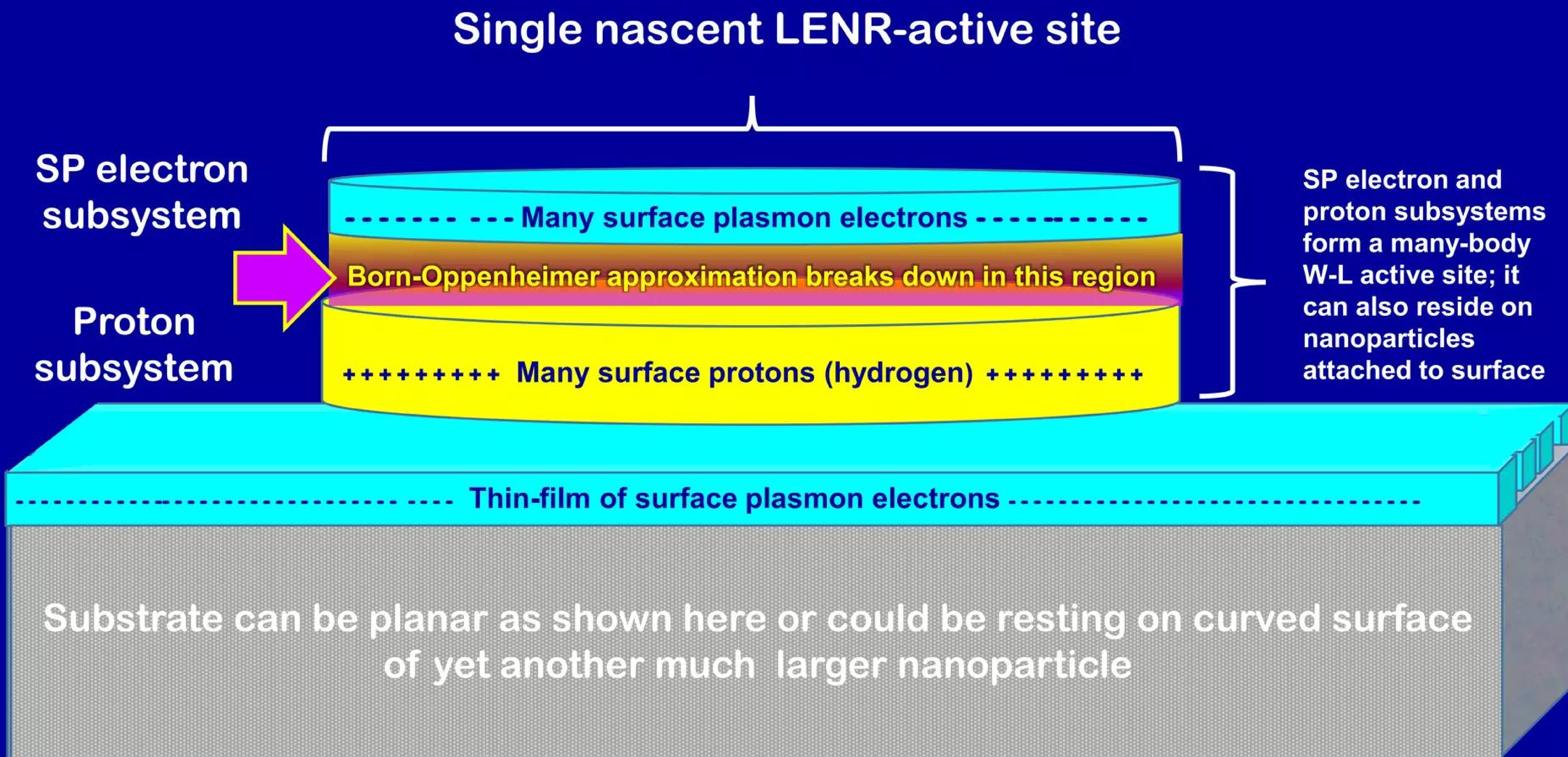


W-L concept of a microscopic LENR-active surface site

Comprised of many-body patches of protons and electrons on surface

SP electrons and protons oscillate collectively and are mutually Q-M entangled

Diameters of many-body active sites randomly range from several *nm* up to ~ 100^{+} microns



Input energy creates high electric fields in LENR active sites

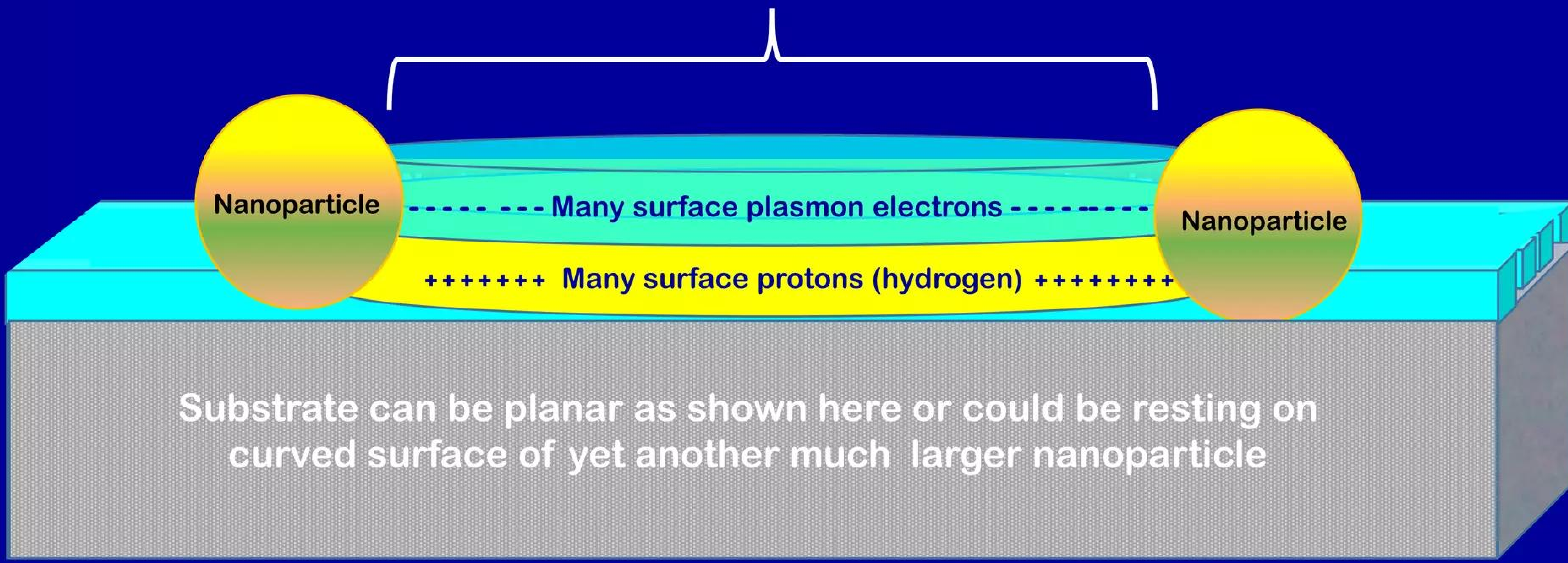
Born-Oppenheimer breakdown enables nuclear-strength local E-field

Huge electric field increase effective masses of some patch SP electrons

Correct input energies create huge local E-fields > 2.5 x 10^{11} V/m between adjacent nanoparticles

Input energy$_{\text{E-field}} + e^{-}_{sp} \rightarrow e^{-*}_{sp} + p^{+} \rightarrow n + \nu_e$ **[condensed matter surfaces]**

Single nascent LENR-active site



LENRs occur in microscopic active sites found on surfaces

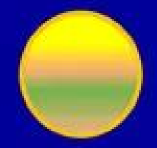
Many-body collections of protons and electrons form spontaneously

Ultralow energy neutrons produced & captured close to LENR-active sites

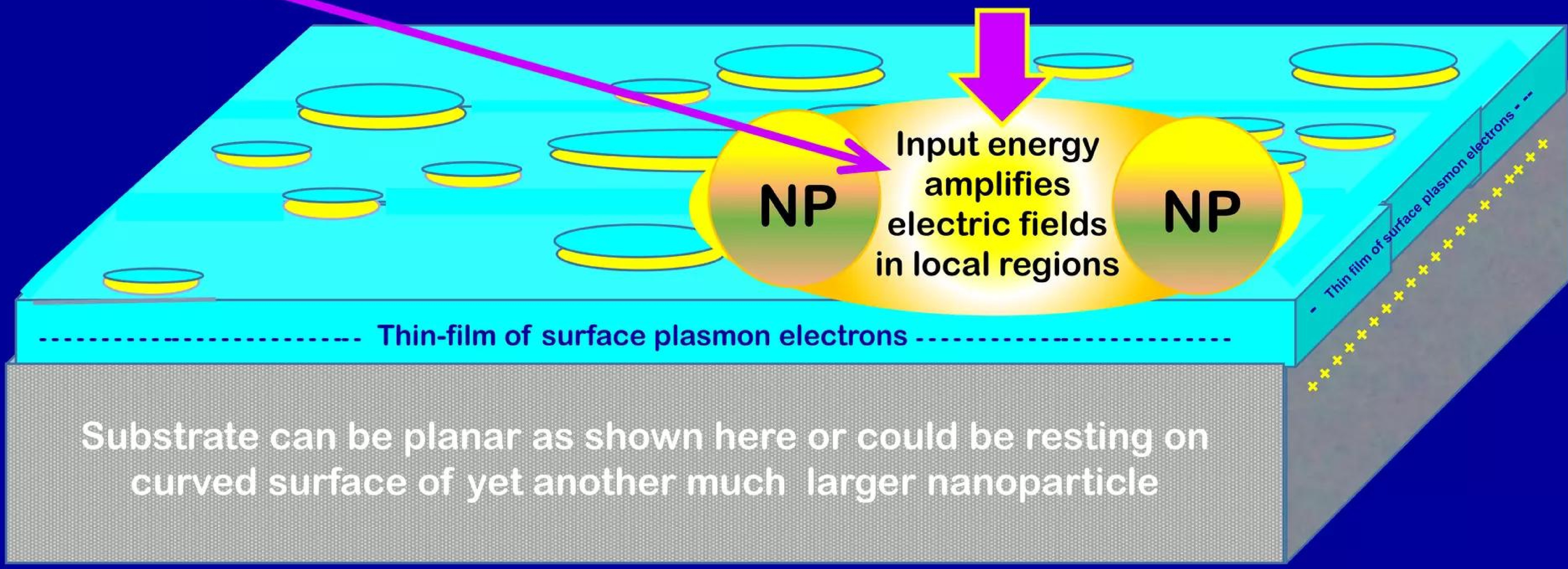
Intense heating in LENR-active sites will form μ-scale event craters on substrate surfaces

After being produced, neutrons capture on atoms in/around active sites:

$n + (Z, A) \rightarrow (Z, A+1)$ [neutrons capture on nearby fuel targets]

$(Z, A+1) \rightarrow (Z + 1, A+1) + e_{\beta}^{-} + \nu_e$ [beta$^-$ decay]  = nanoparticle

Often followed by β^- decays of neutron-rich intermediate isotopic products



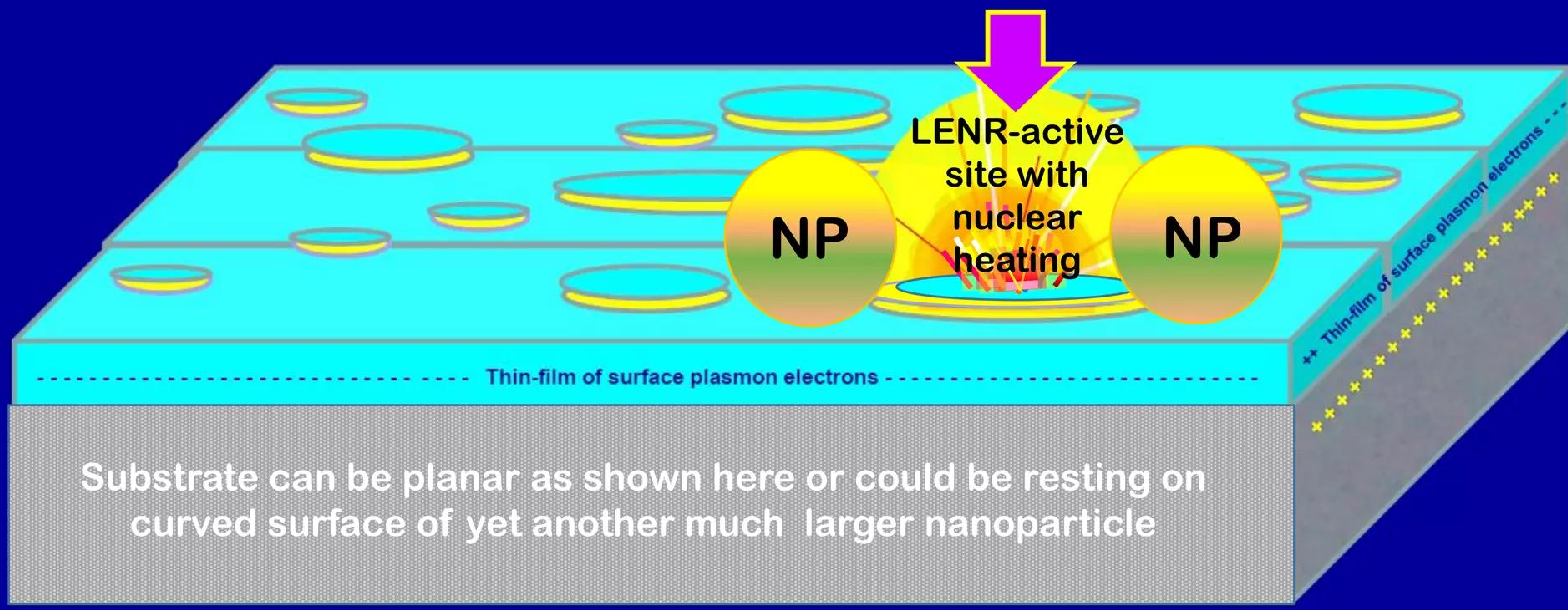
LENR-active sites will only exist for ~200 - 400 nanoseconds

Local heating will destroy needed quantum coherence and site dies

Produced neutrons captured locally → transmutation of fuel elements

Neutron capture process by itself extremely fast: occurs in just picoseconds

Heating in LENR-active sites often creates surface craters ~100 or so microns in diameter. These features can be observed on LENR-active surfaces post-experiment with scanning electron microscopes (SEM); wide variety of LENR transmutation products have been observed in exactly the same areas with SIMS



Nucleosynthesis via W-L-S electroweak neutron production

Not just on hot stars --- also in condensed matter at modest temperatures

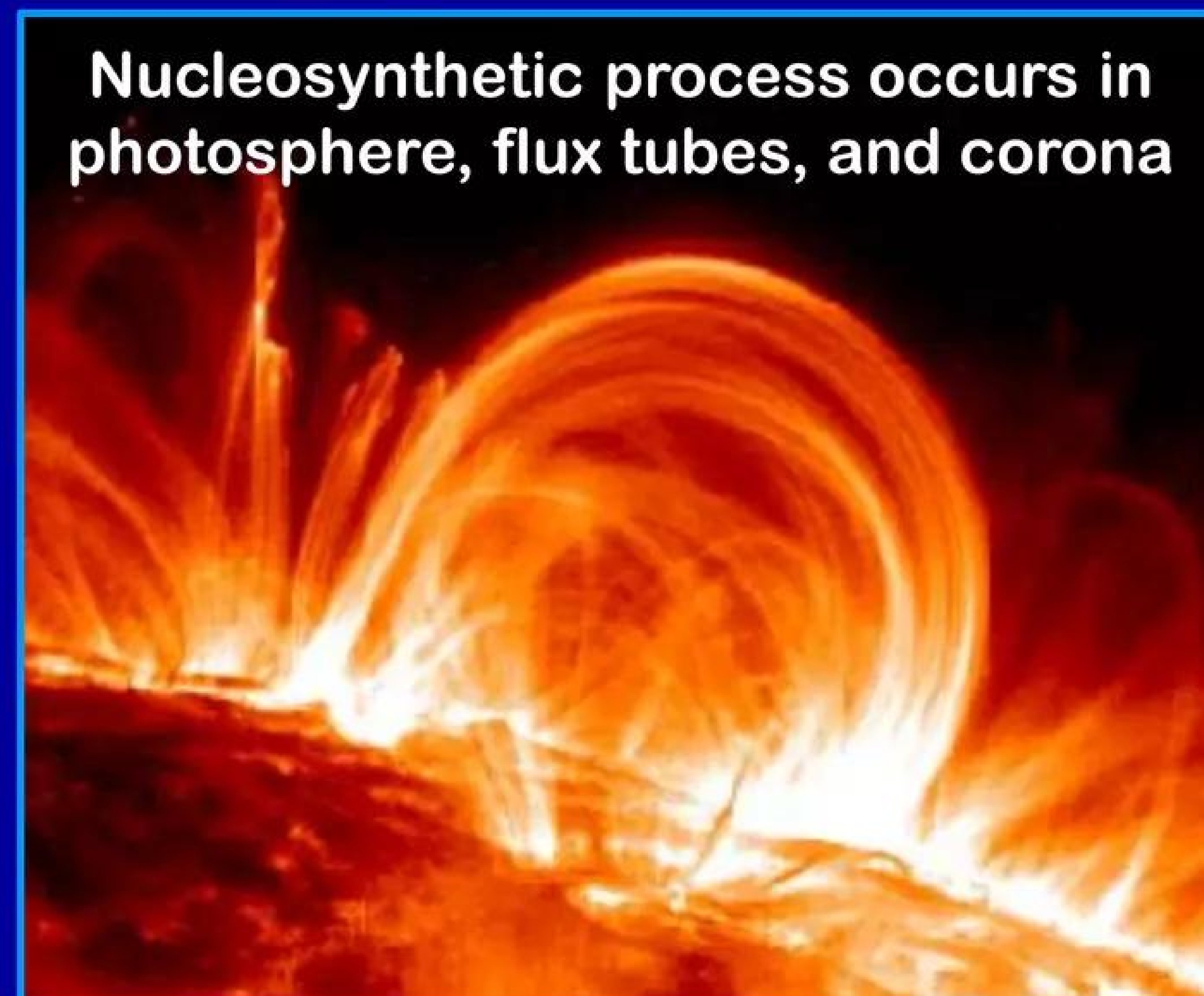
Collective $e + p$ reactions can occur on stars, dust grains in nebulae, and planets

Planetary lightning produces neutrons

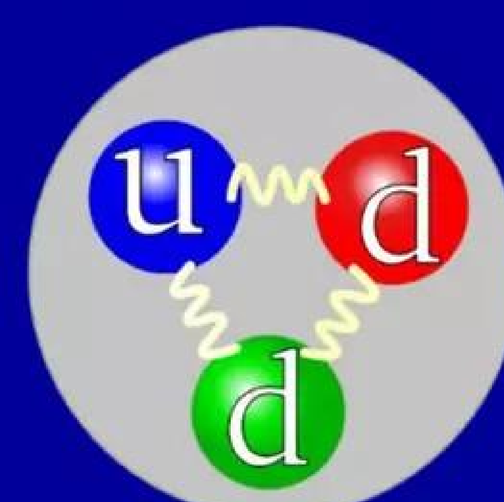
Earth: LENRs occur in many places

Gas-ant planets: Jupiter not failed star

W-L-S operates on the Sun



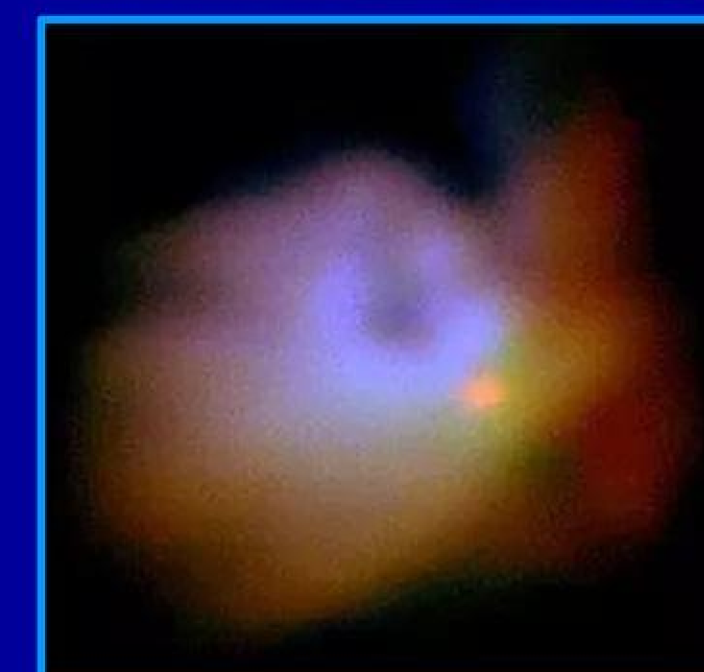
Credit: TRACE image of coronal loops in UV



Quark structure of the neutron - credit: Wikipedia

Very dusty Eagle Nebula

T-Tauri star embedded In nebulosity



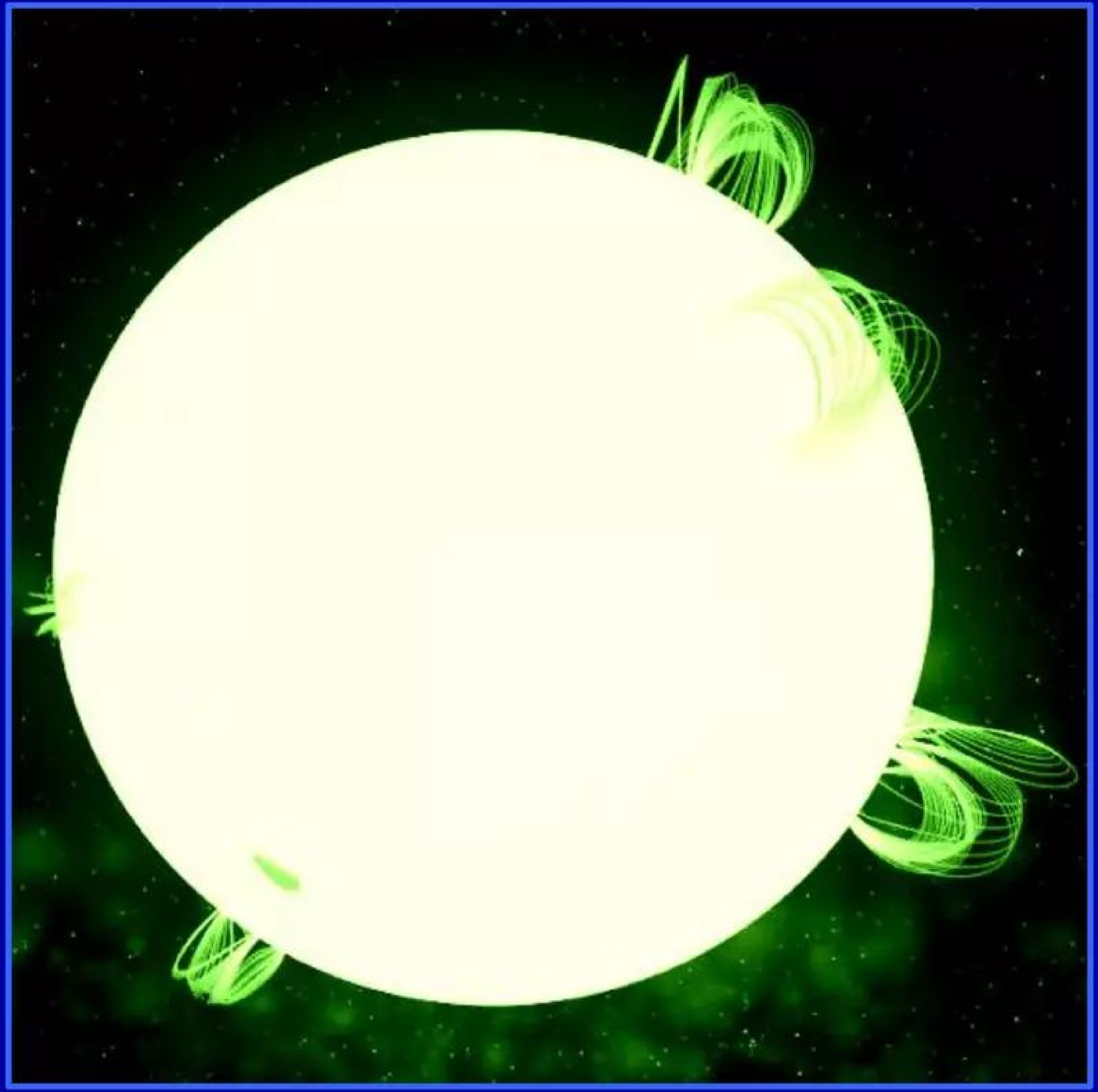
White dwarf stars – don't support fusion

Plasma-filled magnetic flux tubes occur on the Sun

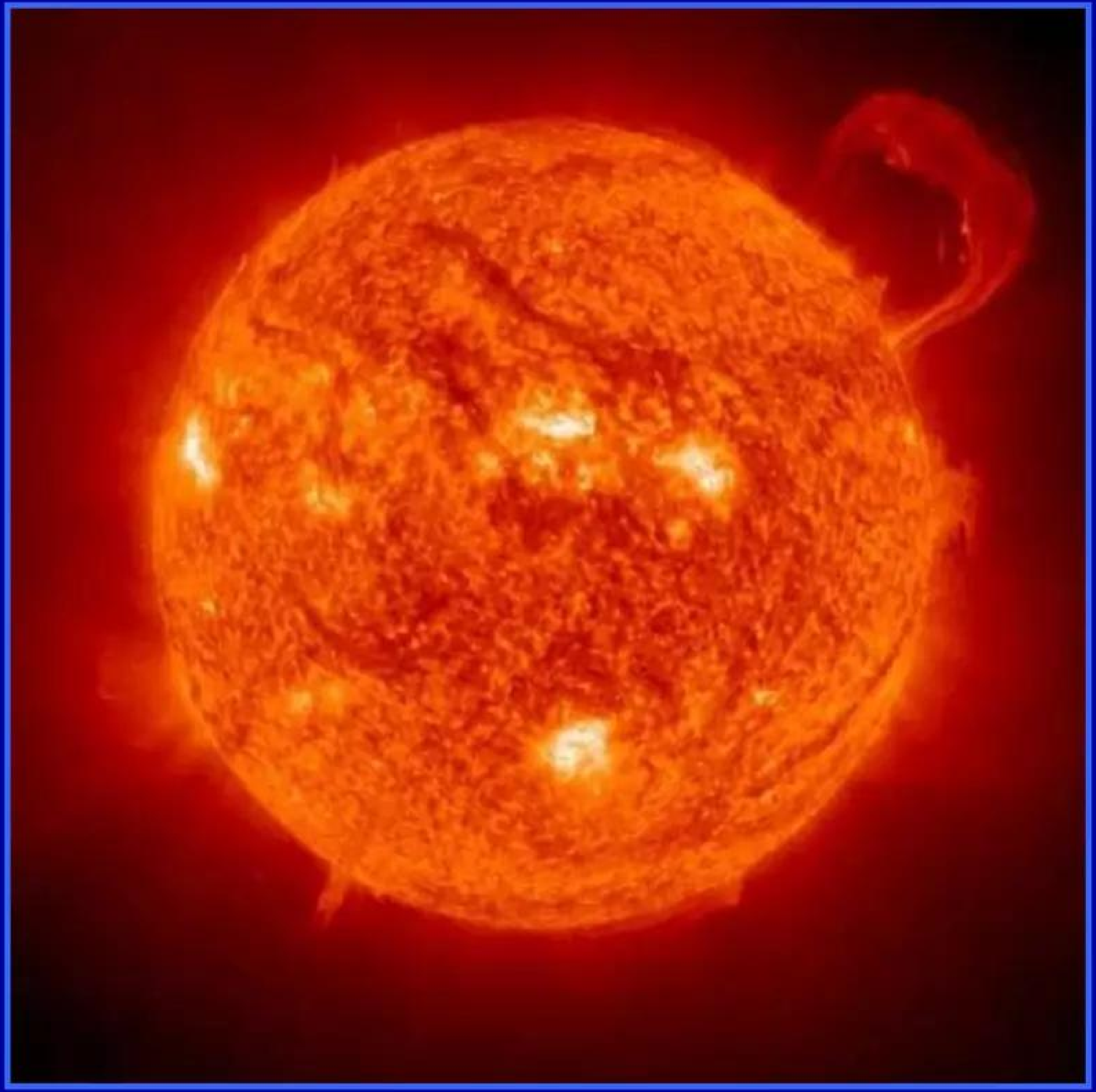
Also called coronal loops; have been observed on other types of stars

These large length-scale ordered magnetic structures quite common in Universe

Idealized graphic of magnetic flux tubes anchored in Sun's surface



Credit: NASA SOHO - false-color image of Sun in extreme ultraviolet



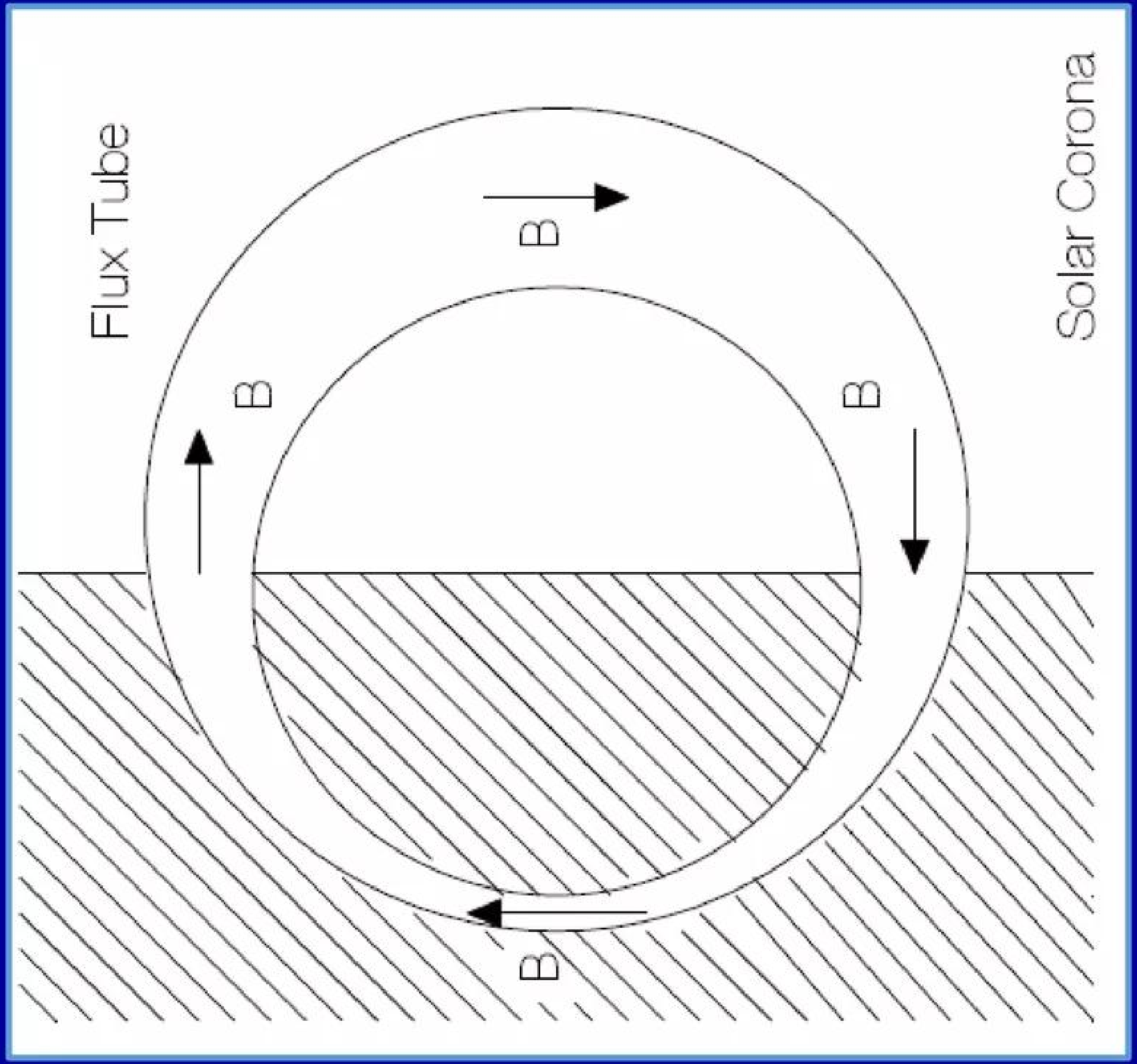
W-L-S posits electroweak $e^{-} + p^{+}$ reactions in coronal loops

Mechanism will accelerate protons and electrons in magnetic flux tubes

Neutron production and nucleosynthesis can occur outside dense cores of stars

Widom, Srivastava & Larsen (2008)

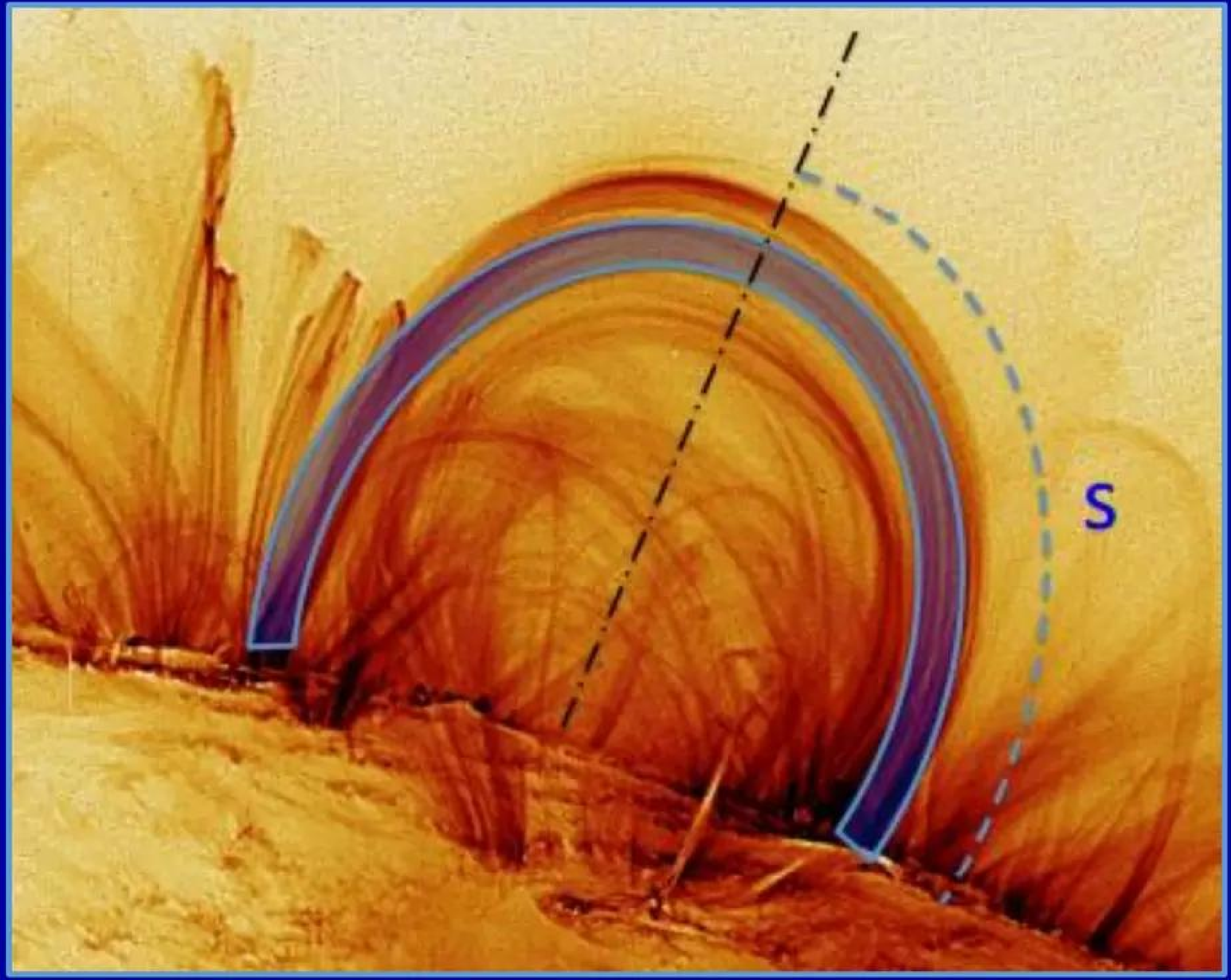
Fig. 1 - Magnetic flux tube



http://arxiv.org/pdf/0804.2647.pdf

F. Reale (2014)

Fig. 12 - Plasma confined in a loop



http://solarphysics.livingreviews.org/Articles/lrsp-2014-4/download/lrsp-2014-4Color.pdf

Many-body collective $e + p$ reactions occur on the Sun

Quoted from "A primer for electro-weak low energy nuclear reactions"

Nucleosynthesis and energetic particle production occurs in magnetic flux tubes

- ✓ "If and when the kinetic energy of the circulating currents in a part of the floating flux tube becomes sufficiently high, the flux tube would become unstable and explode into a solar flare which may be accompanied by a coronal mass ejection. There is a rapid conversion of the magnetic energy into charged particle kinetic energy. These high-energy products from the explosion initiate nuclear as well as elementary particle interactions, some of which have been detected in laboratories."
- ✓ "Recent NASA and ESA pictures show that the surface of the Sun is covered by a carpet-like interwoven mesh of magnetic flux tubes of smaller dimensions.* Some of these smaller structures possess enough magnetic energy to lead to LENRs through a continual conversion of their energy into particle kinetic energy. Occurrence of such nuclear processes in a roughly steady state would account for the solar corona remaining much hotter than the photosphere."
- ✓ "... our picture belies the notion that all nuclear reactions are contained within the core of the Sun."
- ✓ "On the contrary, it provides strong theoretical support for experimental anomalies such as short-lived isotopes that have been observed in the spectra of stars having unusually high average magnetic fields."

* - idea of small loops in 'carpet' is supported by experimental data of H. Peter *et al.*, *A&A* (2013)

Many-body collective $e + p$ reactions occur on the Sun

W-L-S equations for calculation of center-of-mass acceleration energy

Accelerated particles center-of-mass energy for exploding flux tube

$$e\mathcal{V} \approx (30 \text{ GeV}) \left(\frac{B}{\text{kG}}\right) \left(\frac{\pi R^2}{\Lambda - \text{km}}\right)$$

Eq. (20) in *Pramana* paper (2010)

- ✓ In 2008 (*arXiv*) and 2010 (*Pramana*), we derived and published approximate, rule-of-thumb formulas for calculating estimated one-shot, mean center-of-mass acceleration energies for charged particles present in plasma-filled magnetic flux tubes (also called "coronal loops") for two cases: (1) steady-state and (2) explosive destruction of an unstable flux tube (this second case is subset of "magnetic reconnection" processes)
- ✓ These relatively straightforward relationships were discovered in the process of elaborating and extending our theory of many-body collective effects and electroweak reactions involving protons and electrons in condensed matter systems on small length-scales (where short-range, ultra-high strength electric fields dominate) to analogous, much larger-scale electromagnetic systems in which magnetic fields dominate and provide input energy required to drive certain types of electroweak processes, produce pair plasmas, and create elemental nucleosynthesis
- ✓ Our simple equations for magnetic flux tubes are robust and scale-independent. They consequently have broad applicability from exploding wires (which in early stages of explosion comprise dense dusty plasmas), lightning, to solar flux tubes and other astrophysical environments that are characterized by vastly higher magnetic fields; these include many other types of stars besides the Sun, neutron stars, magnetars, and regions located near black holes and active galactic nuclei

Solar flares can produce complex mixtures of products

Many-body collective effects enable electron-proton electroweak reactions

Collective many-body electroweak reactions require input energy

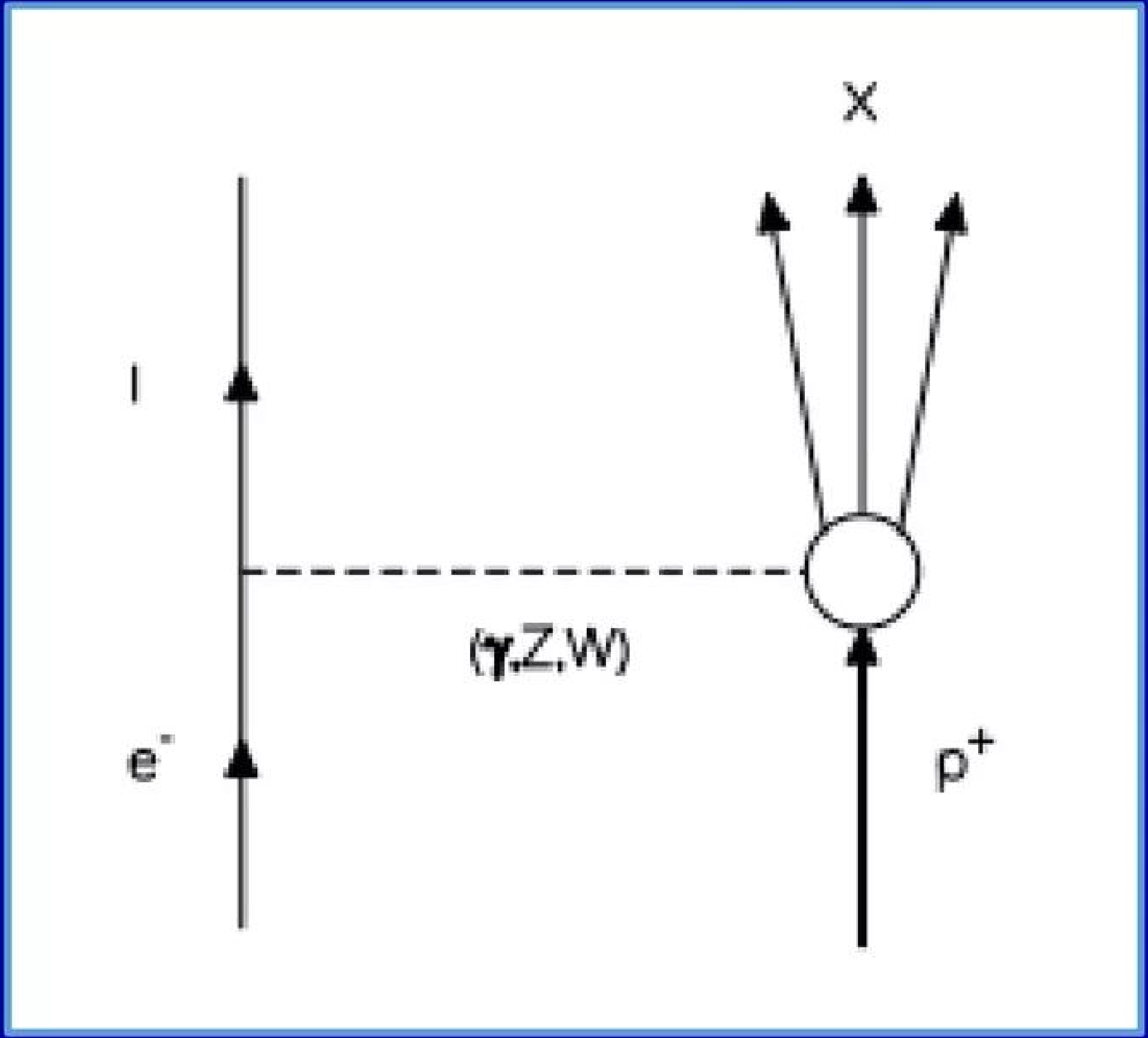
$$e^{-*} + p^{+} \rightarrow n + \nu_e$$
$$e^{-} + p^{+} \rightarrow lepton + X$$

When electric fields dominate

Magnetic fields dominate at very high energies in plasmas

- ✓ FIG.2 shows the electro-weak boson exchange Feynman diagram for electron-proton scattering in colliding electron and proton beams inside a plasma-filled magnetic flux tube at high energies
- ✓ Expression { $e^{-} + p^{+} \rightarrow l + X$ } includes photon γ and Z exchange wherein the final state lepton is an electron for the case of photon γ or Z exchange and the final state lepton is a neutrino for the case of W^{-} exchange. On an energy scale of ~300 GeV, all of these exchange processes have amplitudes of similar orders of magnitude
- ✓ Solar flare or coronal mass ejecting event is thereby accompanied by an increased emission of solar neutrinos over a broad energy scale as well as relativistic protons, neutrons and electrons. Full plethora of final X states including electron, muon and pion particle anti-particle pairs should also be present in such events

FIG. 2: Boson exchange diagrams for electron-proton scattering into a lepton plus "anything"



"High energy particles in the solar corona"
A. Widom, Y. Srivastava, and L. Larsen
arXiv:nucl-th/0804.2647v1 (2008)

Nucleosynthesis occurs in the atmosphere of the Sun

Many-body collective effects enable electron-proton electroweak reactions

Collective many-body electroweak reactions require input energy

$$e^{-*} + p^{+} \rightarrow n + \nu_e$$
$$e^{-} + p^{+} \rightarrow lepton + X$$

Electric fields dominate

Magnetic fields dominate

- ✓ Conversion of magnetic field energy into relativistic particle kinetic energy via a Faraday law voltage pulse is collective in that the magnetic flux in the core of the vortex depends on the rotational currents of *all* of the initial protons and electrons
- ✓ "On the energy scale $W_{magnetic} \ll 300$ GeV of Eq.(13), the weak interaction $p^{+} e^{-}$ processes Eq.(7) that produce neutrons proceed more slowly than the purely electromagnetic $p^{+} e^{-}$ processes. Nevertheless one finds appreciable neutron production in the solar corona. The production of neutrons among the protons allows for the creation of nuclei with higher mass numbers via neutron capture nuclear reactions and subsequent beta decays." arXiv:nucl-th/0804.2647v1
- ✓ Relativistic neutrons produced by high-energy electroweak $e + p$ reactions in plasma-filled magnetic flux tubes will have low capture cross-sections on seed elements per the 1/v proportionality rule. Nonetheless, neutron-driven nucleosynthesis (albeit at vastly lower rates vs. supernovas) akin to astrophysical *r*- and *s*-processes can occur in and near such commonplace magnetic structures found in varied astrophysical environments including stars' atmospheres, on accretion disks, and near black holes
- ✓ Nucleosynthesis occurs in regions besides stellar cores and supernova explosions

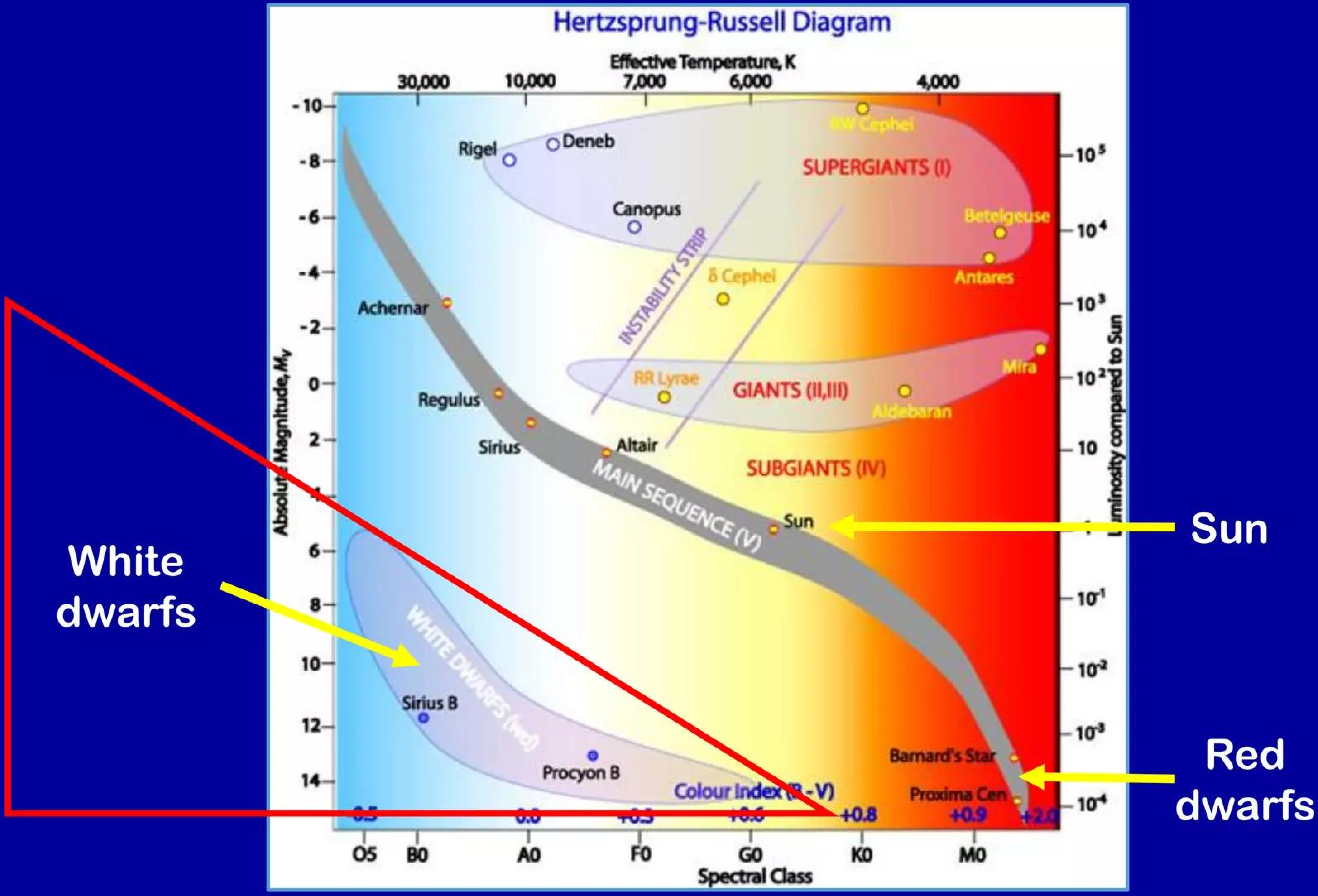
Tatischeff et al. proposed nucleosynthesis in stellar flares

"Nucleosynthesis in stellar flares"
V. Tatischeff, J-P. Thibaud, and I. Ribas arXiv preprint (2008)
http://arxiv.org/PS_cache/arxiv/pdf/0801/0801.1777v1.pdf\

- ✓ "The solar-flare gamma-ray line emission testifies that fresh nuclei are synthesized in abundance in energetic solar events ... Solar-type activity is believed to be a phenomenon inherent to the vast majority if not all main-sequence stars. The Sun is not an active star in comparison with numerous stellar objects in the solar neighbourhood that show much higher luminosities in emissions associated with coronal and chromospheric activities. Although gamma-ray line emission from other flaring stars cannot be observed with the current sensitivity of the gamma-ray space instruments, it is more than likely that the Sun is not the only star producing surface nucleosynthesis in flares."
- ✓ "Enormous enhancements of accelerated ^{3}He are measured in impulsive solar flares: the $^3He/\alpha$ ratios found in these events are frequently three to four orders of magnitude larger than the corresponding value in the solar corona and solar wind, where $^3He/^4He \sim 5 \times 10^{-4}$."
- ✓ "Asplund et al. have recently reported the detection of ^{6}Li at $\geq 2\sigma$ confidence level in nine halo stars of low metallicity, [Fe/H] < -1, situated in the turnoff region of the Hertzsprung-Russel diagram. The ^{6}Li abundances measured in these objects are far above the value predicted by Big Bang nucleosynthesis and cannot be explained by galactic cosmic-ray interactions in the interstellar medium either."

Ex-core nucleosynthesis at very low rates may be common

Plasma-filled magnetic flux tubes occur on *many* different types of stars

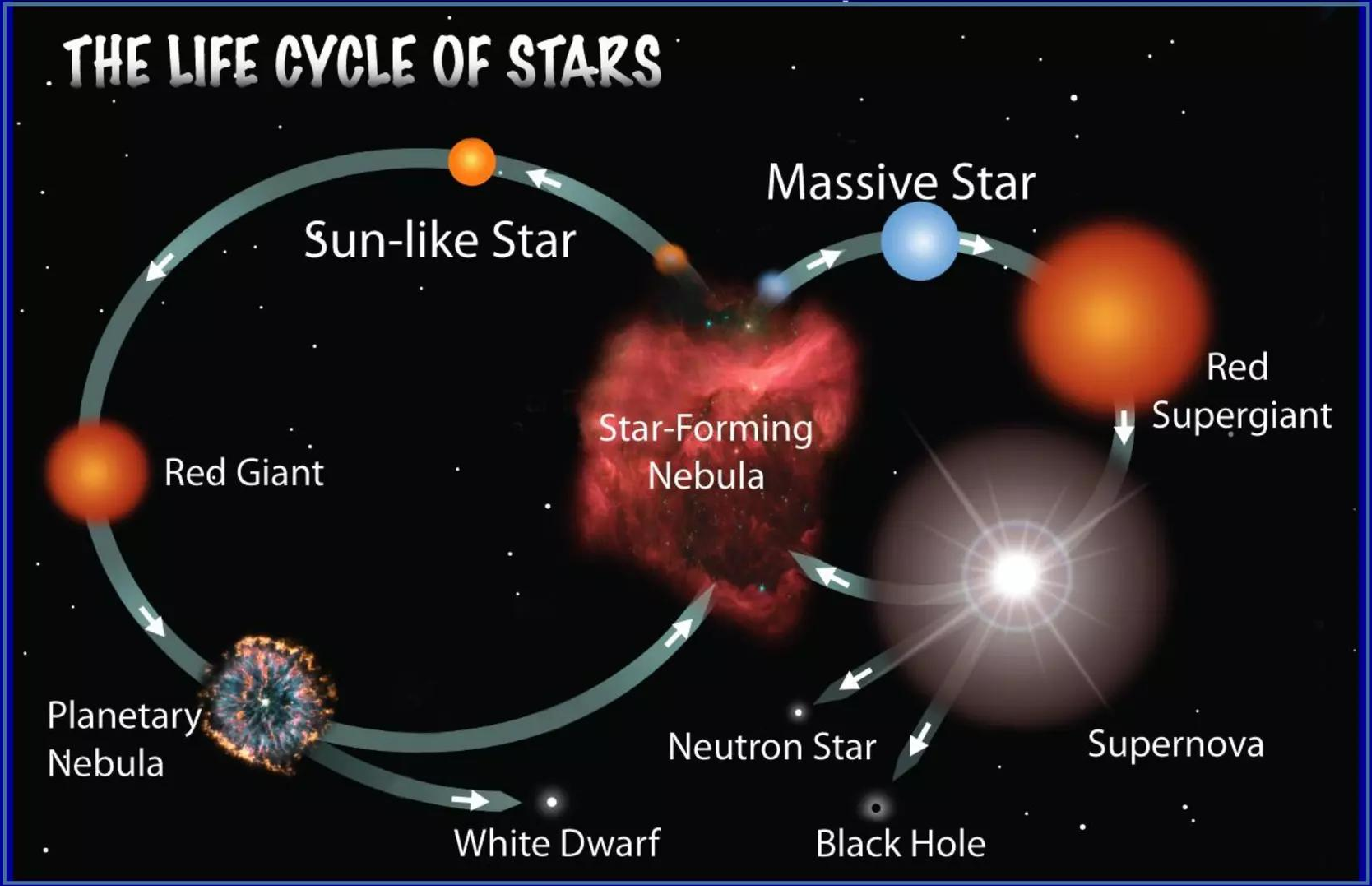


Credit: CSIRO - Australia Telescope National Facility

White dwarfs are evolutionary endpoints of Sun-like stars

White dwarfs can experience much milder explosive events called novas

Nova ejecta nebulae are enriched in elements that include He, C, N, O, Ne, and Mg



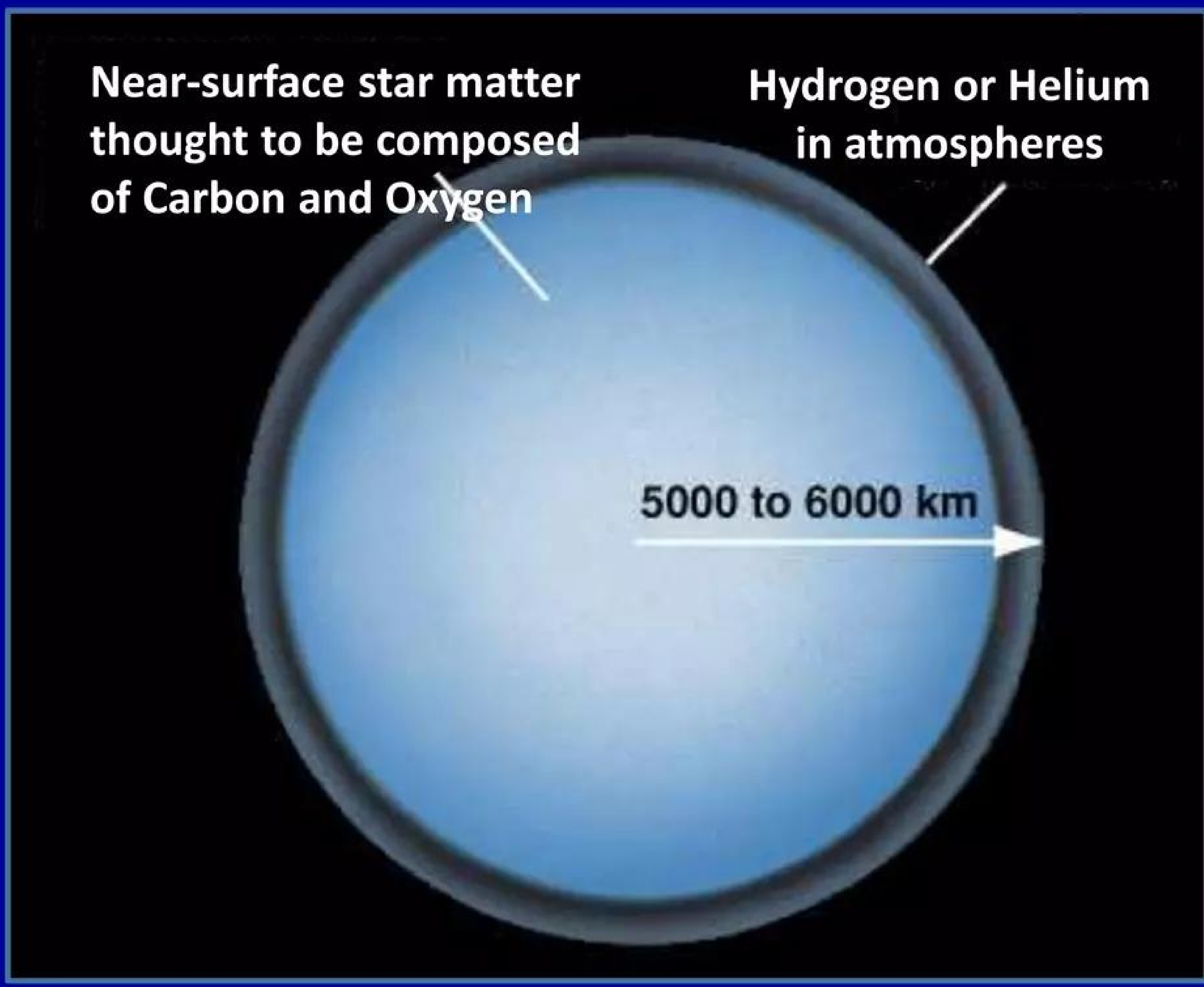
Source: http://www.cmso.info/lifecycst

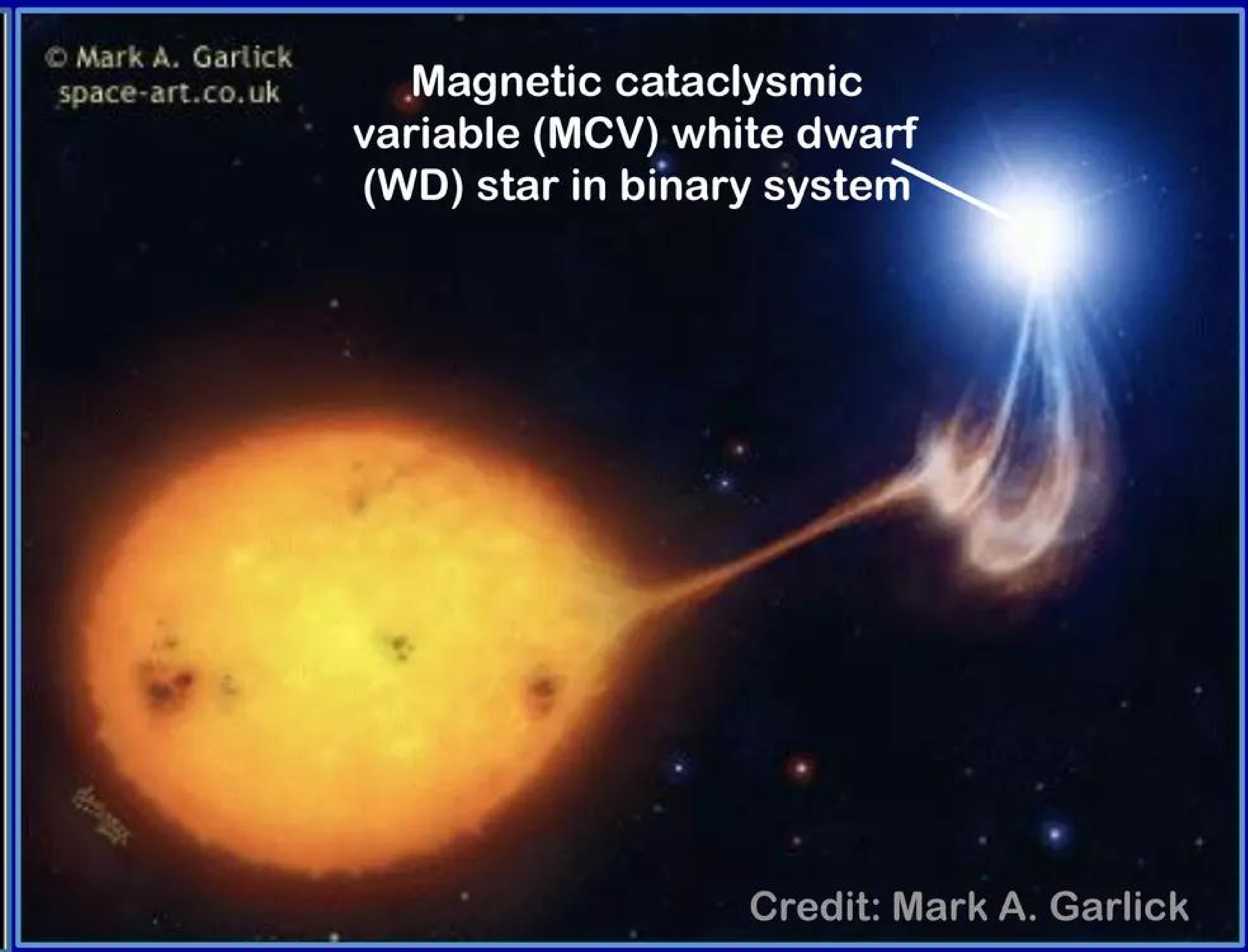
White dwarf stars are size of earth but ~same mass as Sun

Core not hot enough for fusion: nucleosynthesis assumed to be absent

Near-surface is composed of Carbon and Oxygen; either H or He in atmospheres

Huge gravity at surface; some white dwarfs have surface magnetic fields of up to 10^9 Gauss



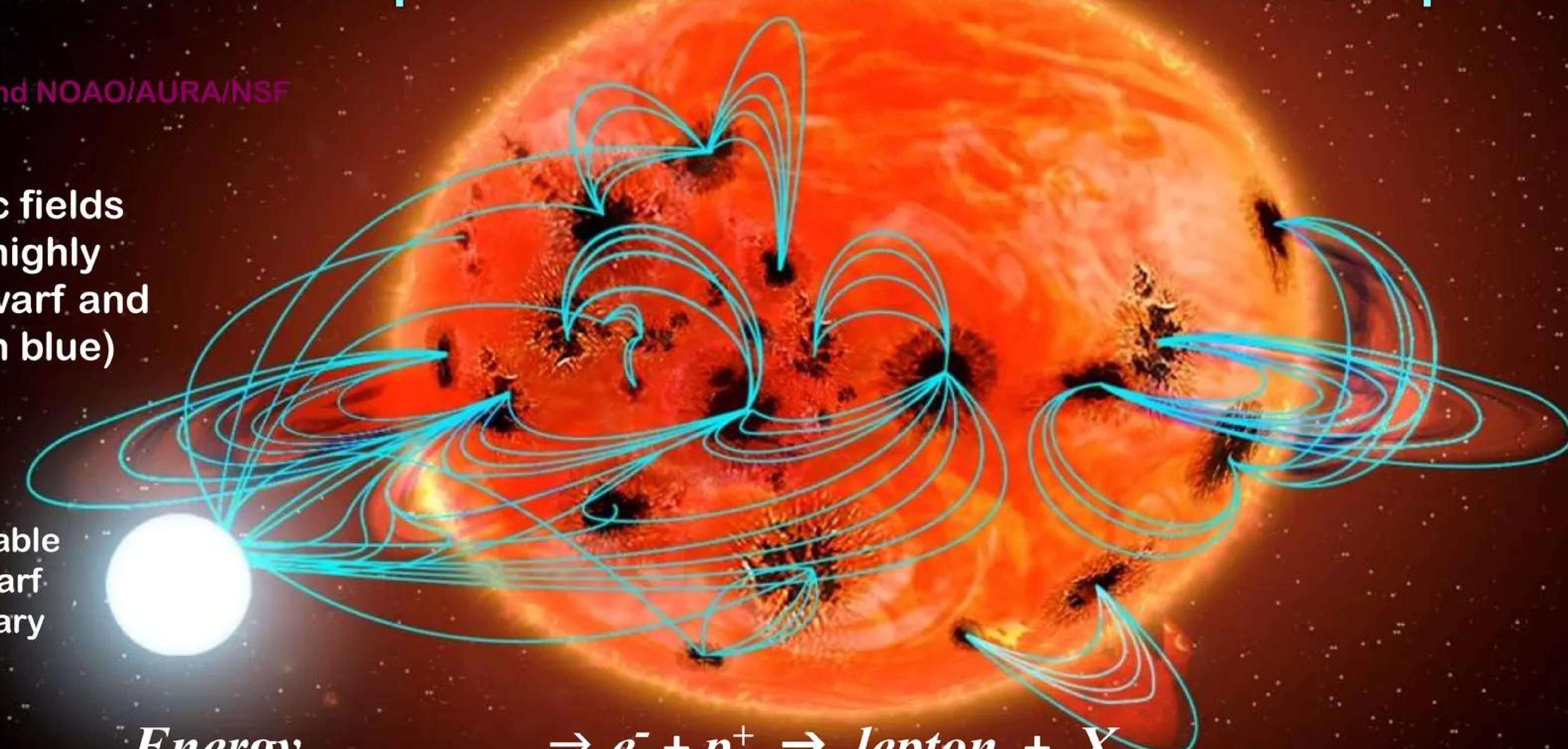


Most abundant elements observed in WD atmospheres: Hydrogen (in 80% of WD stars); Helium (19.9%); and Carbon (0.1% - only in very hottest). Near-surface elemental composition of star (not directly observed or measured – inferred by theoretical astrophysicists) is varying mixture of Carbon, Oxygen, and degenerate electrons. Super-dense hot cores comprised of (inferred, not directly observed) mixtures of all elements heavier than Oxygen and degenerate electrons

Plasma-filled magnetic flux tubes can occur on both stars

Gigantic proton and electron currents flow to pole region of white dwarf

Magnetic electroweak neutron production near MCV white dwarf and companion



$$Energy_{magnetic\ field} \rightarrow e^- + p^+ \rightarrow lepton + X$$

"Artist's concept shows an interacting binary star system known as a polar (or a magnetic cataclysmic variable - MCV). The white star is a very dense, highly magnetic white dwarf in which the magnetic poles of the star are not aligned with its rotation axis. The cool, low-mass red star is distorted due to the strong gravity of the much more massive white dwarf. New research has provided the first direct observational evidence that significant stellar activity in the red star (such as large starspots, prominences, and flares) can be induced by interactions with the strong magnetic field of the white dwarf (blue lines), a phenomenon dubbed hyperactivity."

https://www.noao.edu/outreach/press/pr07/pr0701.html

White dwarf stars not hot enough for fusion in their cores

No active nucleosynthesis of elements should be occurring inside them

As a consequence spectral lines seen in atmospheres should show only H and He

Absence of fusion reactions in white dwarf cores has three key consequences:

- ✓ If nucleosynthesis and transmutation of elements are not occurring in WDs, then their overall elemental composition should be unchanging over time. Given huge densities and gravitational field gradients, elements present inside should settle-out and sort themselves spontaneously by atomic mass (A), with the heaviest sinking deepest into the core. Elements in WDs should be highly stratified and separated into layers like an onion; layer-cake structures would form rapidly after star is born
- ✓ Absence of an internal fusion energy source in cores makes it near-impossible to disrupt stars' interiors, dredge-up dense higher-A elements, transport them upward to stellar surfaces, and then emit them into externally observable atmospheres. Also, degenerate electrons are excellent conductors of heat created during stellar formation, so temperature gradients between surface and core are minimized which helps limit convective admixing of materials between layers of elements inside WDs
- ✓ Given the above, spectroscopically observed composition and abundances of elements present in WD stars' atmospheres should be relatively static --- invariant over time --- and with few exceptions comprised of almost entirely the very lightest gaseous elements, e.g. Hydrogen and/or Helium, as observed on >50% of WD stars

Anomaly: some white dwarfs show elements heavier than He

Said to be "polluted" by external sources that provide heavier elements

- ✓ For 26 - 50% of isolated white dwarfs, spectroscopic observation of their atmospheres have detected lines of number of elements heavier than Helium
- ✓ Unexpected persistence of these spectral features over protracted time periods was regarded as unusual because heavier elements should rapidly sink down into WD cores and become invisible to spectroscopy. Depending on the star, this sinking and disappearance process would require as little as 12 hours but more typically on the order of several weeks or thereabouts. Given that no fusion-driven creation of elements is occurring inside these stars, dredge-up processes should be limited, absent rare nova-type flare explosions on their outer surfaces
- ✓ Consequently, astrophysicists believe that these elemental anomalies must be explained by hypotheses that invoke ongoing and persistent external sources that can inject a suite of heavier elements into white dwarf atmospheres over time
- ✓ Sources thought to contribute to "pollution" of WD atmospheres with heavier elements are:
  - Dusty circumstellar accretion disks and/or any surviving rocky planetesimals
  - Recent nova or dwarf nova mega-flare explosions that occurred on surfaces
  - Magnetic cataclysmic variables (MCVs) that are members of binary systems in which both stars are interconnected by plasma-filled magnetic flux tubes

Possible external sources of heavier elements to WD stars

Problem: there is subset of white dwarfs for which these are implausible

- ✓ **Dusty circumstellar accretion disks and/or surviving rocky planetesimals:** perhaps the most plausible input source comprises constantly infalling condensed matter and/or plasmas emanating from dusty irradiated circumstellar accretion disks or from any remaining planetesimals that somehow managed to successfully survive the fiery expansion and collapse phases of red giant stars that can give birth to white dwarfs
- ✓ **Previous novas or dwarf novas that recently occurred on WD surfaces:** these exceedingly rare and generally highly visible events are capable of dredging-up materials from deeper layers inside WD stars and triggering local fusion-driven nucleosynthesis of elements up through the atomic mass of Nickel (Ni; A ~ 58). On average, only ~ 40 novas per year are thought to occur in our Milky Way galaxy, so phenomenon is rare. Supernovas are even rarer; only 1 - 2 per century in our galaxy
- ✓ **Magnetized white dwarfs and extreme MCVs situated in binary star systems:** these peculiar stars have extremely high surface magnetic fields that can range from 2×10^3 to as much as 10^9 gauss (G); it is believed that 10% of magnetic WDs have fields > 10^6 G. By contrast, average field strength on Sun's surface is 0.5 G but can reach several thousand gauss inside magnetic flux tubes. MCV subset comprises ~10% of WDs with binary companion stars in close orbits; atmospheres of the two stars are thought to be interconnected by plasma-filled magnetic flux tubes and in case of MCV WDs are believed to be concentrated on one of its two magnetic poles. Companions of MCVs are generally low-mass stars with active fusion processes in their cores but some have been reported to be either neutron stars or possibly stellar-mass black holes

Many remaining questions about metal-rich white dwarfs

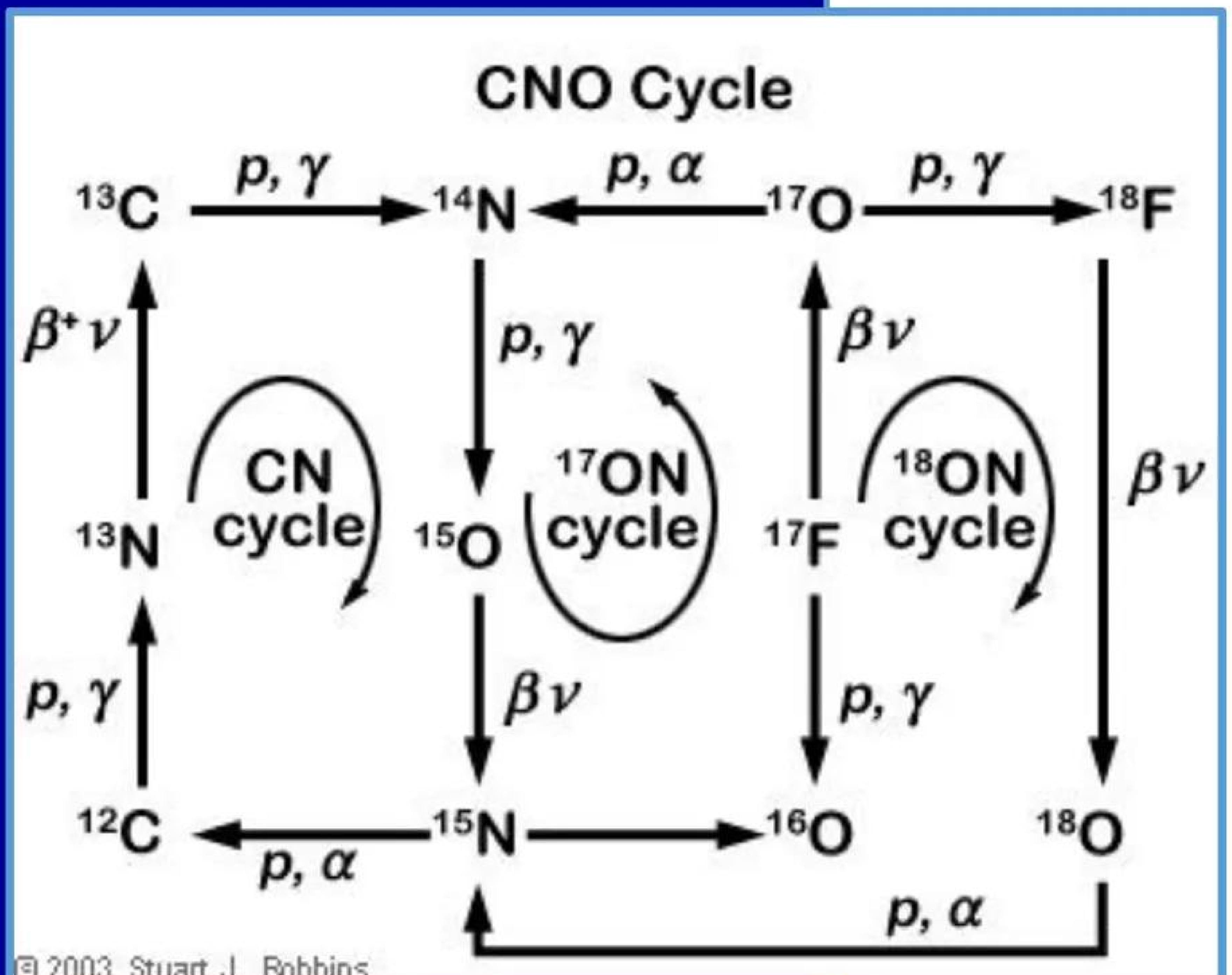
Presence of heavier elements defies easy explanation for some stars

In certain cases ex-core neutron-driven nucleosynthesis may explain data better

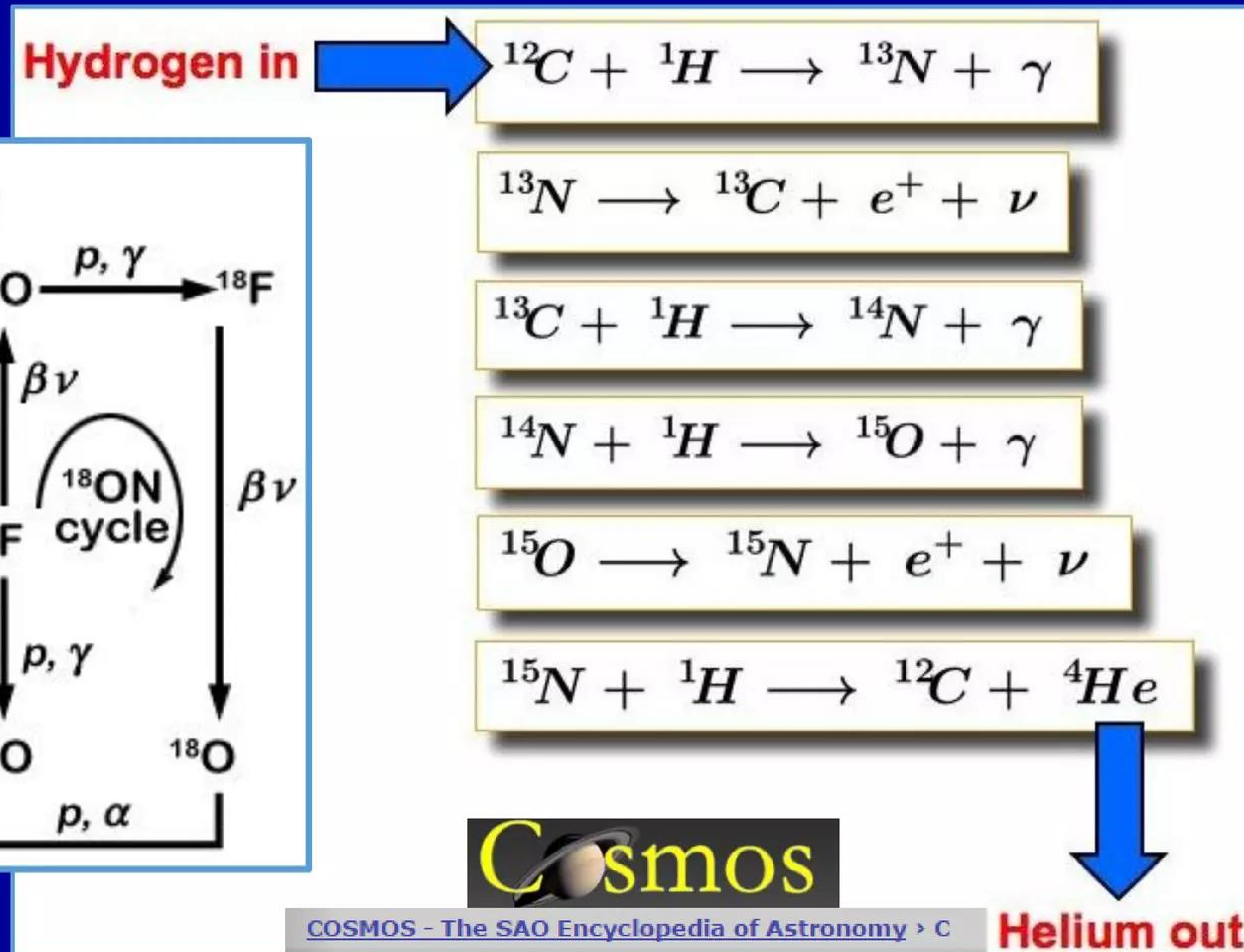
- ✓ In most cases of WD pollution, capture of condensed matter materials from external accretion disks, recent nova explosions on surfaces, and/or exchange of hot plasmas via magnetic flux tubes interconnecting companion stars in binary systems are able to provide adequately satisfying explanations for data about heavier elements detected spectroscopically in white dwarf atmospheres
- ✓ However, there is a significant subset of these polluted WD stars in which such temporally persistent sources of unexpected elements are either inadequate or seemingly absent. For example, in certain cases involving isolated metal-rich WD stars there is no excess infrared radiation emitted from the vicinity that would signal presence of circumstellar accretion disks, nor is there an evidence for recent nova hyperflare events on the star, nor is there any observational data suggesting which suggests that any planetesimals are transiting the star. What then --- *ad hoc* explanations invoking recent undetected novas or asteroid captures? In binary systems lacking any accretion disks or known planetesimals, it is simply assumed that that anomalous elements in a WD were created in the companion star and then transported over to the WD via interconnecting plasma-filled magnetic flux tubes
- ✓ We believe many of such difficult-to-understand pollution datasets can be resolved and explained by relaxing the long-held assumption that no local nucleosynthesis is happening in these enigmatic WD systems. In particular, we propose that many-body collective electroweak neutron production is occurring and causes some anomalies

Carbon → Nitrogen → Oxygen nucleosynthetic pathways

Charts show how fusion-based CNO cycles thought to operate in stars



Credit: Stuart J. Robbins (2003)



Comments: in stellar CNO fusion cycle only ^{12}C is recycled; in LENR-based carbon cycles, ^{12}C, ^{13}C, and ^{14}C are all potentially regenerated. ULM neutron-capture driven LENR networks in condensed matter systems will produce vastly more neutron-rich isotopes than stellar fusion and neutron capture processes in hot plasmas: e.g., $^{12}C \rightarrow {}^{20}C$; $^{14}N \rightarrow {}^{23}N$; $^{19}O \rightarrow {}^{24}O$; $^{19}F \rightarrow {}^{27}F$; and $^{20}Ne \rightarrow {}^{27}Ne$. Alpha decays are much more common in CNO fusion reactions

Production of Nitrogen-15 in supernova (SN) explosions

Fig. 3: how B. Meyer & M. Bojazi believe process works in supernovas

"Sensitivity of Nitrogen-15 production in explosive helium burning to SN energies"

"Production of ^{15}N is from abundant ^{14}N via the reaction $^{14}N(\alpha, \gamma)^{18}F$ followed by $^{18}F(n, \alpha)^{15}N$ or by $^{18}F(n, p)^{18}O$ followed by $^{18}O(p, \alpha)^{15}N$."

"Destruction of ^{15}N is by the reactions $^{15}N(\alpha, \gamma)^{19}F$ and $^{15}N(p, \alpha)^{12}C$. The ^{15}N abundance first builds up, but, as the source ^{14}N is depleted, destruction flows dominate and the ^{15}N abundance declines."

Presentation at 44th Lunar and Planetary Science Conference (2013)

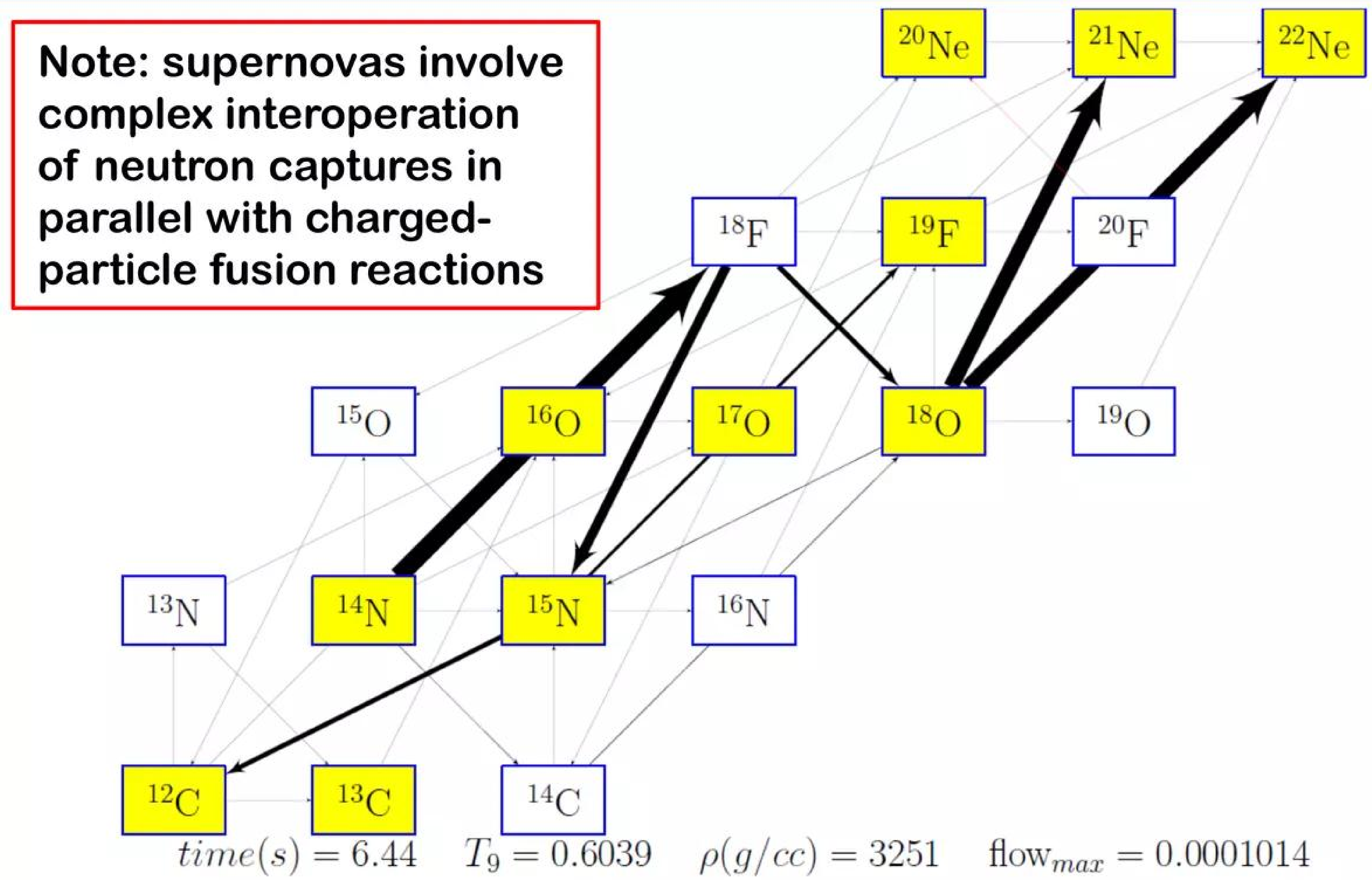


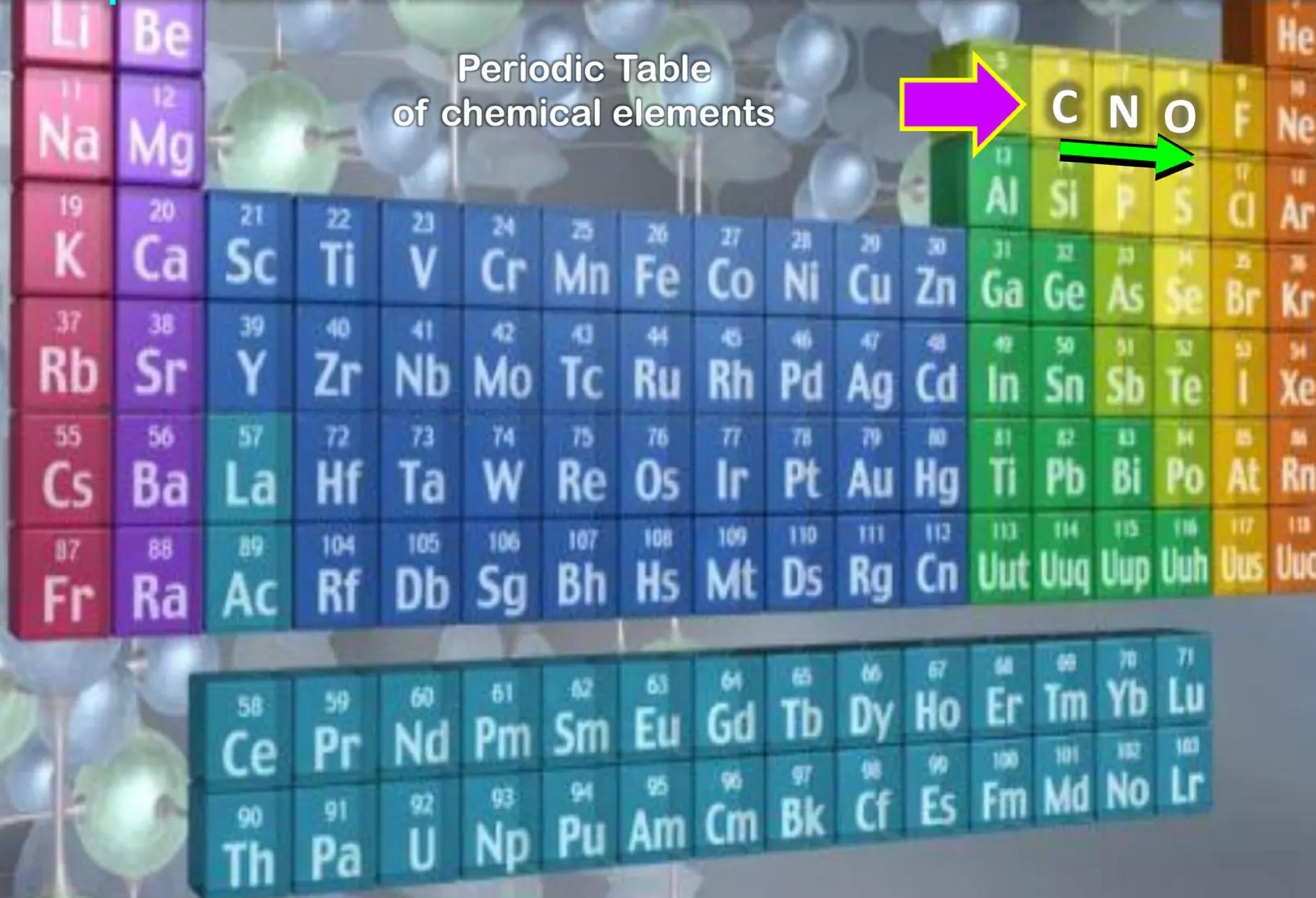
Fig. 3. Reaction flows for zone 601 at a particular point in the E = 5.0 x 10^{50} ergs calculation. The thickness of the arrow gives the strength of the flow.

http://www.lpi.usra.edu/meetings/lpsc2013/pdf/3006.pdf

W-L theory processes go left-to-right across rows of Table

Reactions can produce Nitrogen and Oxygen from Carbon without fusion

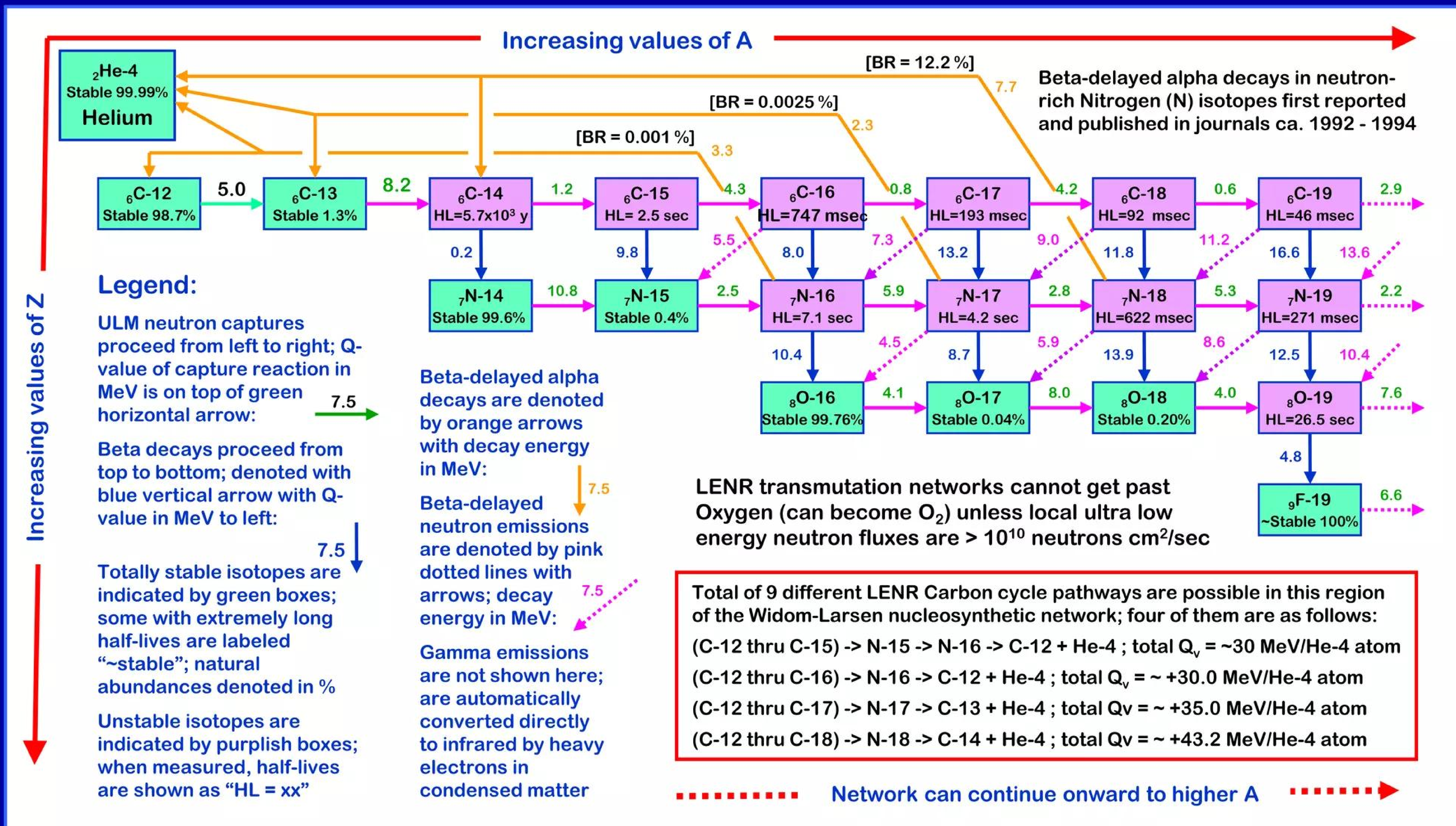
Next slides explain details of reactions in LENR transmutation of C into N and O



LENR network can begin with neutron captures on Carbon

Creates Nitrogen, Oxygen and heavier A depending on neutron fluxes

Network can produce Helium via alpha-decay of neutron-rich Nitrogen isotopes

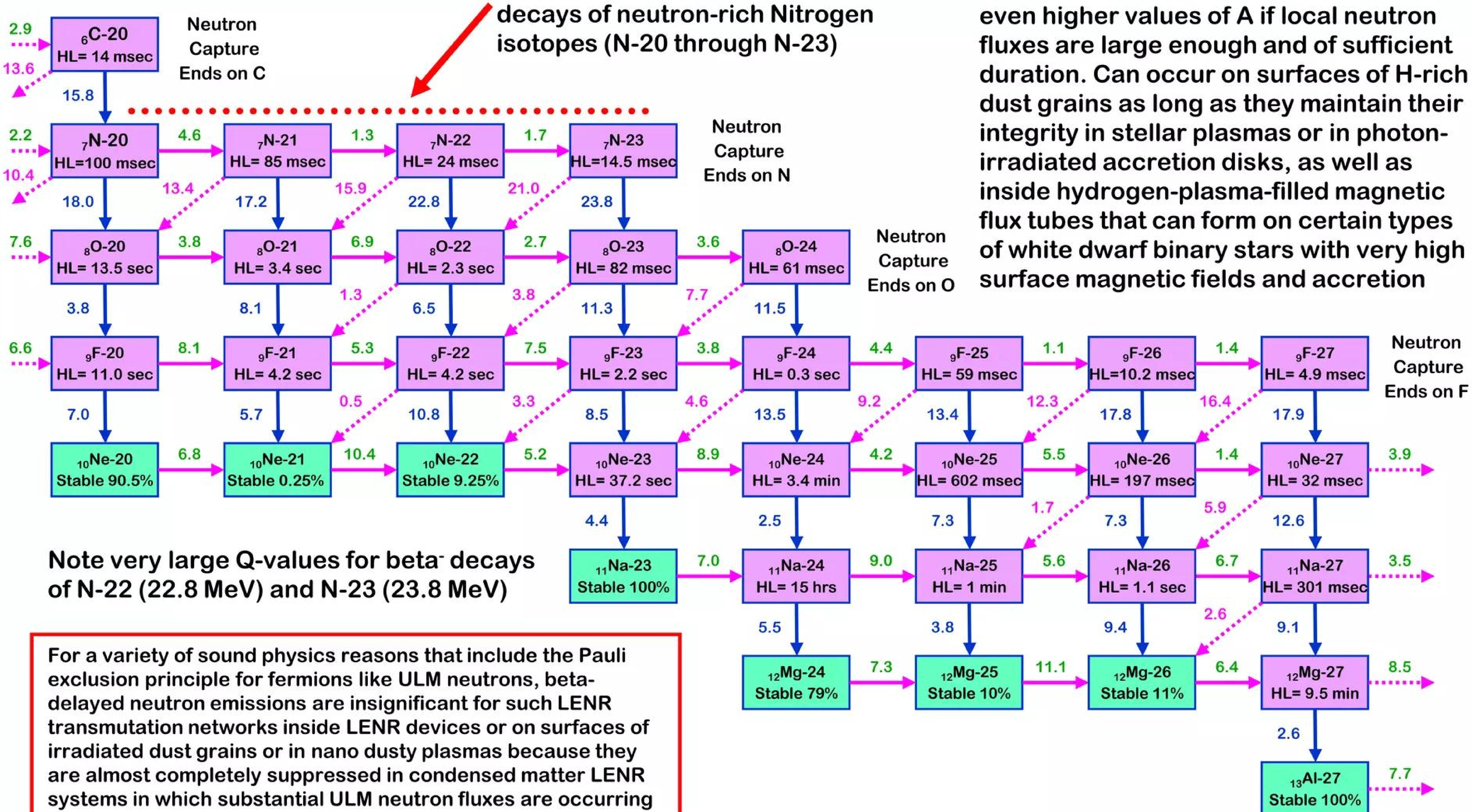


Network reaches Aluminum with sufficient neutron fluxes

Produces same suite of elements as a nova without any fusion reactions

See region of very high-energy beta$^-$ decays of neutron-rich Nitrogen isotopes (N-20 through N-23)

LENR transmutation networks can reach even higher values of A if local neutron fluxes are large enough and of sufficient duration. Can occur on surfaces of H-rich dust grains as long as they maintain their integrity in stellar plasmas or in photon-irradiated accretion disks, as well as inside hydrogen-plasma-filled magnetic flux tubes that can form on certain types of white dwarf binary stars with very high surface magnetic fields and accretion



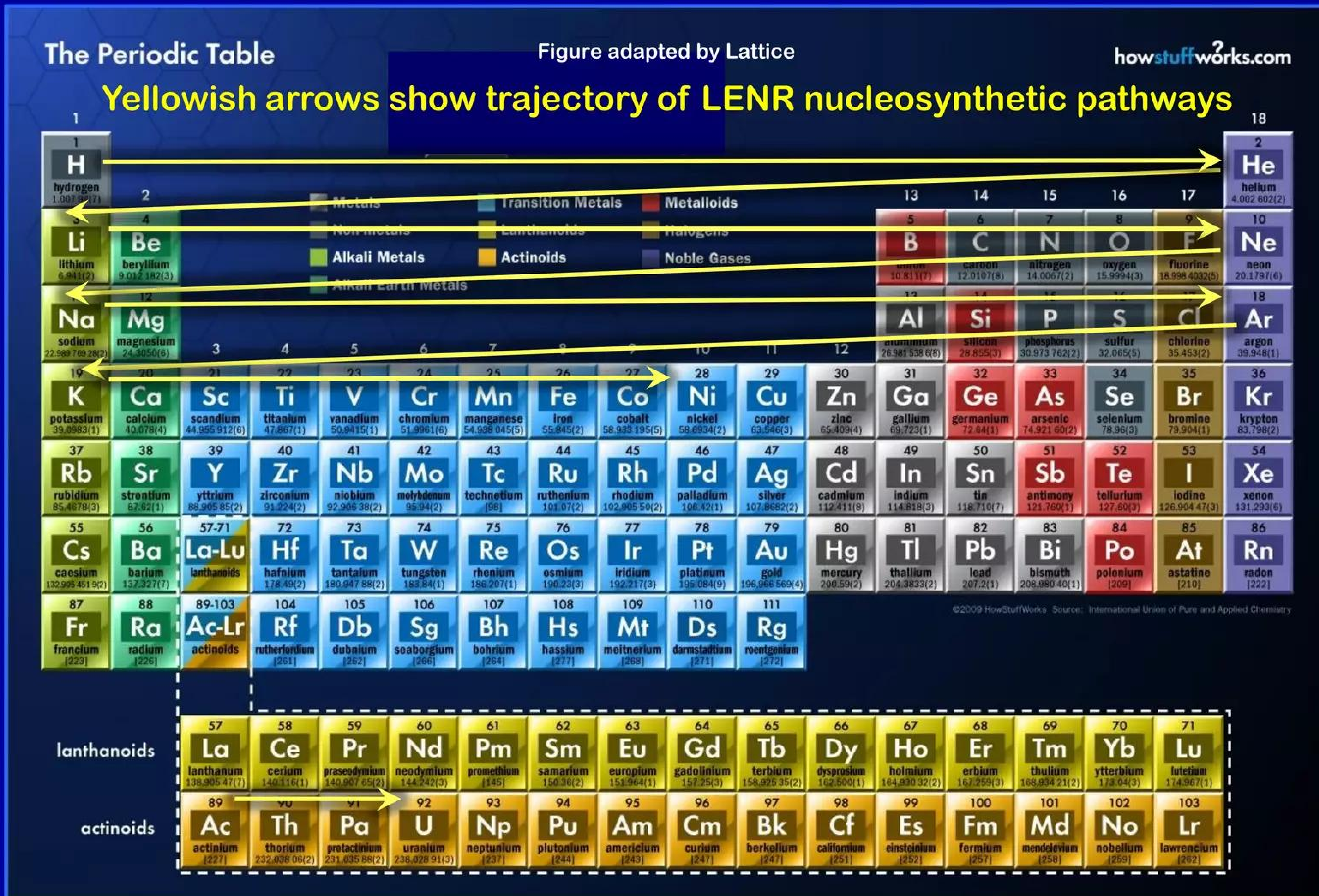
Note very large Q-values for beta$^-$ decays of N-22 (22.8 MeV) and N-23 (23.8 MeV)

For a variety of sound physics reasons that include the Pauli exclusion principle for fermions like ULM neutrons, beta-delayed neutron emissions are insignificant for such LENR transmutation networks inside LENR devices or on surfaces of irradiated dust grains or in nano dusty plasmas because they are almost completely suppressed in condensed matter LENR systems in which substantial ULM neutron fluxes are occurring

Network can produce Nickel with sufficient neutron fluxes

LENR pathway from Al → Ni is series of neutron captures and β^- decays

Fusion processes and LENRs can both create elements in astrophysical settings

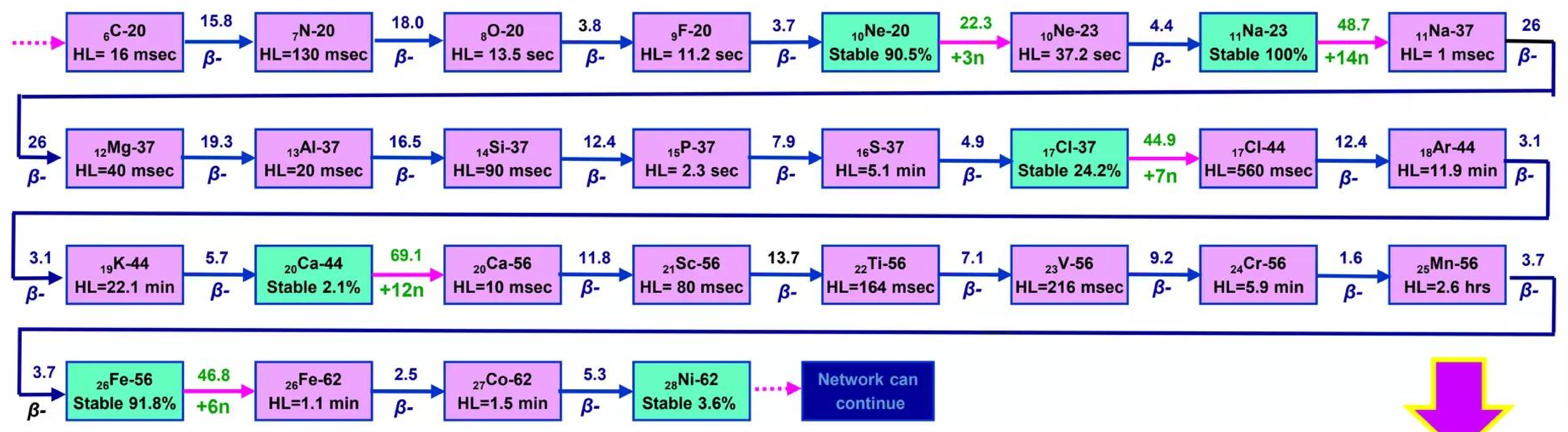


Network can produce Nickel with sufficient neutron fluxes

Summary diagram shows one potential pathway from Carbon to Nickel

Q-value for pathway is very energetically favorable and makes Ni within 3.4 hours

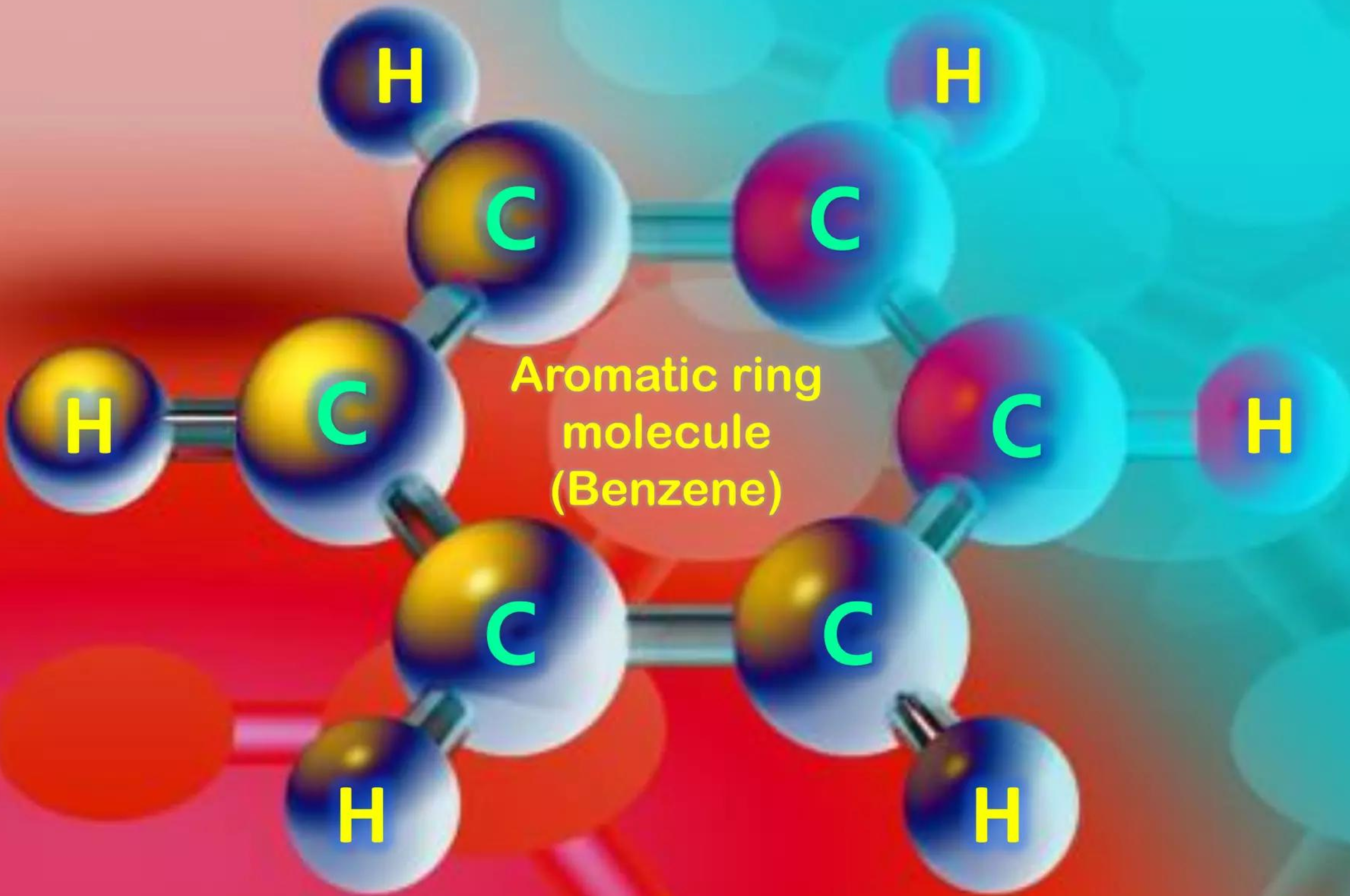
Theorized favorable pathway begins at C-20 in Carbon-seed LENR network shown on previous slide



Total Q_v from C-20 thru Fe-56 = 385.7 MeV; sum of half-lives (HL) from C-20 thru Fe-56 = ~3.4 hrs

Stable nuclei produced by this theorized LENR reaction pathway typically have high natural abundances, specifically Ne, Na, Fe. Sum of half-lives from C-20 to Fe-56 is a little more than three hours; isotope with the longest half-life just before Fe-56 is Mn-56, which is the key gateway isotope in this transmutation pathway. Practically, this means that in condensed matter systems: (a) some Fe-56 will be synthesized within 3 hours or so after LENR neutron production begins; and (b) within 8 hours after LENR neutron production ends (for whatever reason), most of the unstable intermediate products will have decayed into stable isotopes. Pathway was observed in experiments conducted at Texas A&M and BARC in the mid-1990s

Lattice extends Widom-Larsen theory to aromatic molecules



6 Carbon atoms arranged in hexagonal ring bonded to 6 Hydrogen atoms

Surface plasmons exist on polycyclic aromatic hydrocarbons

Our 2009 conjecture was confirmed by A. Manjavacas *et al*. (March 2013)

"Tunable molecular plasmons in polycyclic aromatic hydrocarbons" A. Manjavacas *et al*. *ACS Nano* 7 pp. 3635 - 3643 (2013) http://pubs.acs.org/doi/abs/10.1021/nn4006297

"Technical Overview - PAHs and LENRs" L. Larsen, Lattice Energy LLC November 25, 2009 (slides # 42 - 45) http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewpahs-and-lenrsnov-25-2009

ABSTRACT: "We show that chemically synthesized polycyclic aromatic hydrocarbons (PAHs) exhibit molecular plasmon resonances that are remarkably sensitive to the net charge state of the molecule and the atomic structure of the edges. These molecules can be regarded as nanometer-sized forms of graphene, from which they inherit their high electrical tunability. Specifically, the addition or removal of a single electron switches on/off these molecular plasmons. Our first-principles time-dependent density-functional theory (TDDFT) calculations are in good agreement with a simpler tight-binding approach that can be easily extended to much larger systems. These fundamental insights enable the development of novel plasmonic devices based upon chemically available molecules, which, unlike colloidal or lithographic nanostructures, are free from structural imperfections. We further show a strong interaction between plasmons in neighboring molecules, quantified in significant energy shifts and field enhancement, and enabling molecular-based plasmonic designs. Our findings suggest new paradigms for electro-optical modulation and switching, single-electron detection, and sensing using individual molecules."

Radiation-free transmutation of Carbon → Nitrogen → Oxygen

Lattice was able to extend Widom-Larsen theory to aromatic molecules

Explains experiments conducted by Mizuno at Hokkaido University in 2008

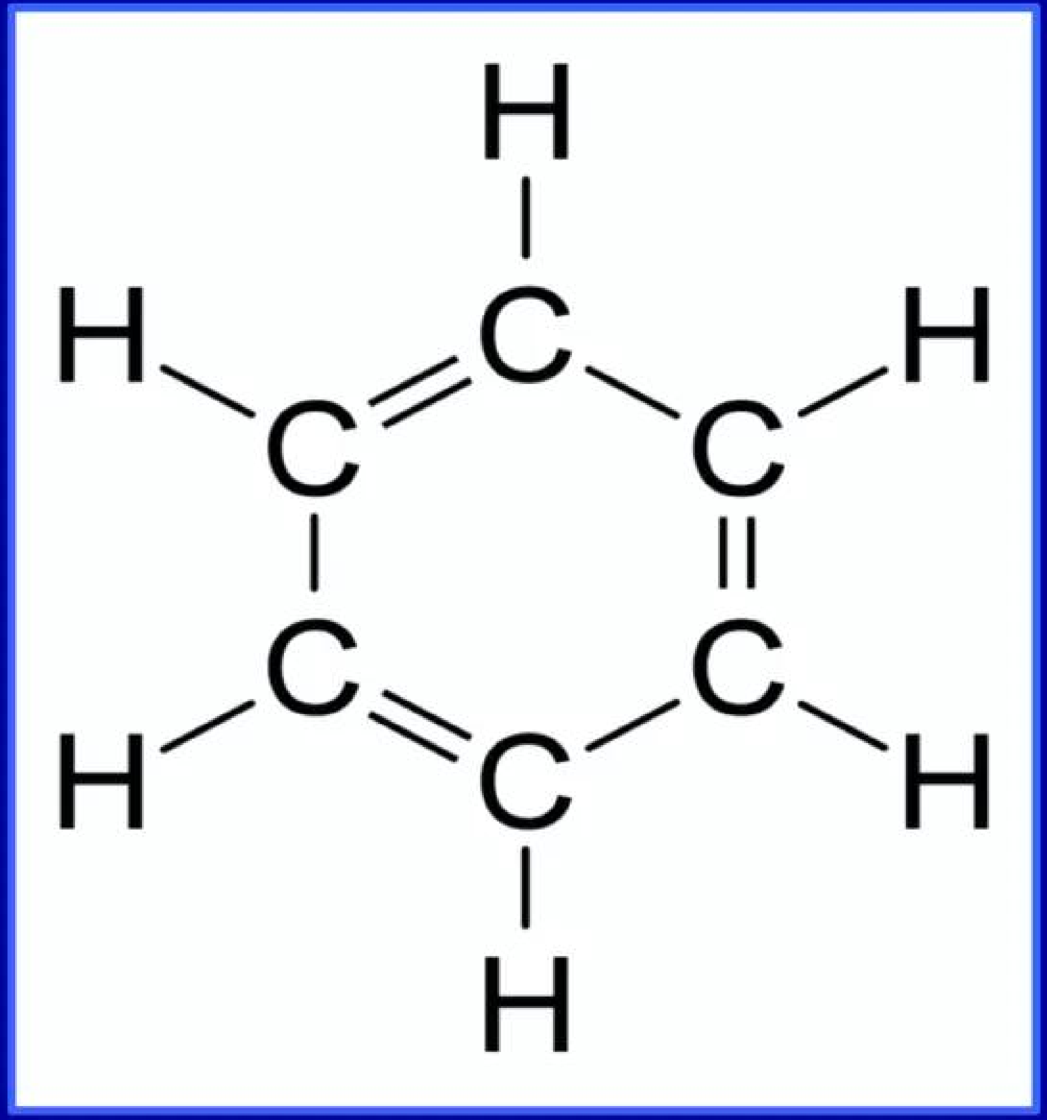
- ✓ Experiments conducted at Hokkaido University (Japan) in 2008 demonstrated that production of LENR neutrons and transmutation of Carbon can be triggered on aromatic rings at very modest temperatures and pressures; these seemingly anomalous results of Mizuno are fully explained by the Widom-Larsen theory
- ✓ Per Widom-Larsen, delocalized π (Pi) electrons e^-_π found on aromatic (benzene-like) rings are quantum mechanically entangled and behave like collectively oscillating surface plasmons on metallic surfaces or at metal/oxide interfaces
- ✓ Similarly, protons p^+ (Hydrogen atoms) attached to ring Carbon atoms oscillate collectively and are also quantum mechanically entangled with each other
- ✓ Per Widom-Larsen, Born-Oppenheimer Approximation breaks-down on aromatic rings which enables local nuclear-strength electric fields that increase effective masses of some π electrons so that they can then react with one of the ring's protons to convert it into an ultra low energy neutron which is captured by a nearby ring Carbon atom. This begins the LENR Carbon transmutation process
- ✓ Series of successive neutron captures and decays make Nitrogen, then Oxygen

Convert ring protons (Hydrogen atoms) into LENR neutrons

Ultra low energy neutrons created collectively in an electroweak reaction

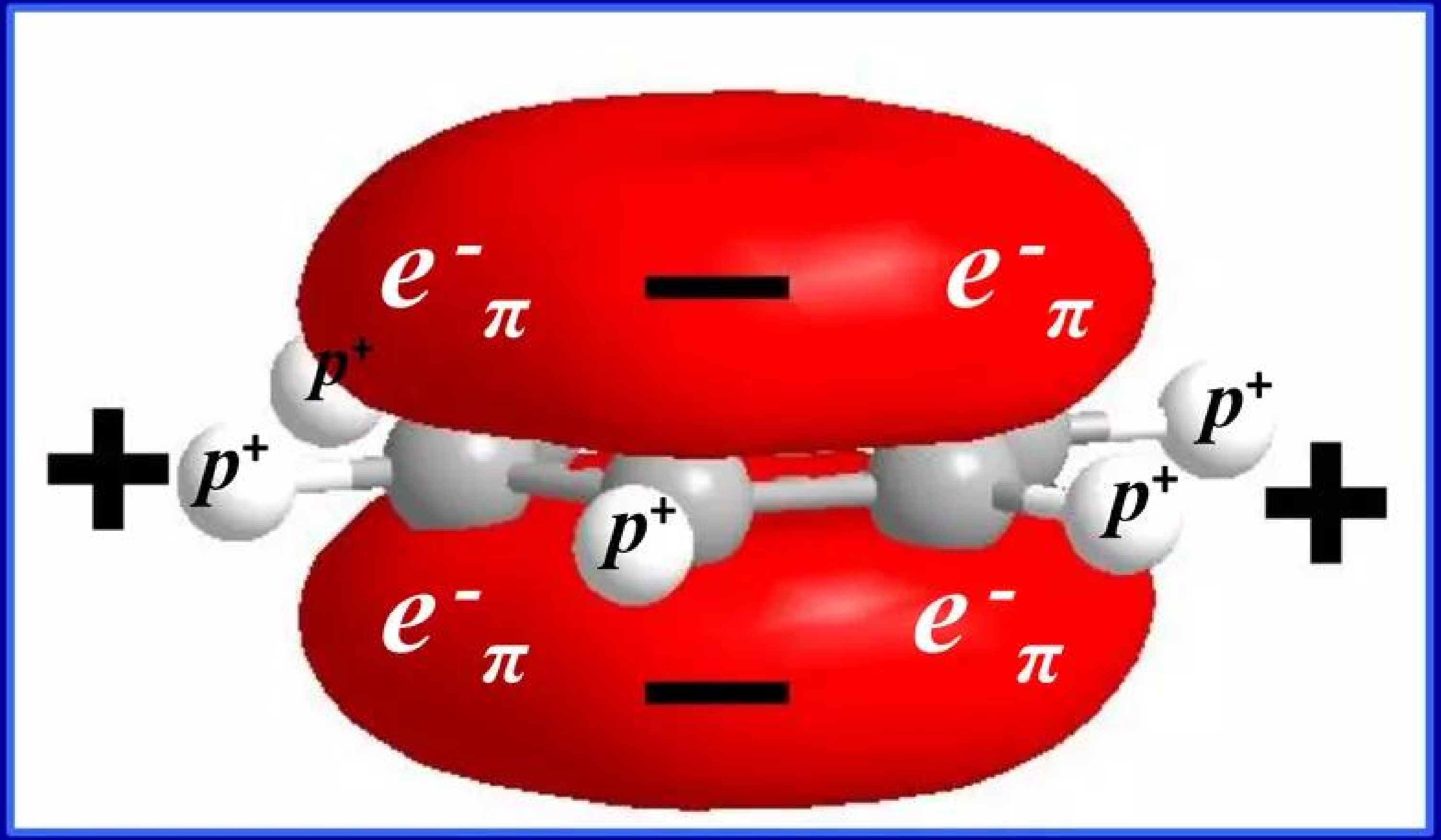
$$\text{Input energy}_{\text{electromagnetic field}} + e^{-}_{\pi} \rightarrow e^{-*}_{\pi} + p^{+} \rightarrow n^{0} + \nu_{e}$$

Each entangled Hydrogen atom contains a single proton bonded to the 6-Carbon ring



Benzene's 6-Carbon ring

Only handful of total number of π electrons shown



Red indicates entangled π (Pi) many-electron clouds on both sides of Benzene ring

For technical discussion and evidence for quantum entanglement in LENR systems see:

http://www.slideshare.net/lewisglarsen/lattice-energy-llc-two-facets-of-wl-theorys-lenractive-sites-supported-by-paper-in-phys-rev-lettjuly-23-2015

Widom-Larsen theory LENR-active site has condensates

Site comprises many-body collective ‘patch’ of protons and plasmons

Born-Oppenheimer breakdown and collective quantum effects enable W-L LENRs

- ✓ “Spatial coherence and stability in a disordered organic polariton condensate”
  K. Daskalakis *et al. Physical Review Letters* 115 pp. 035301 - 06 (2015)
- ✓ Inside a laser-pumped microcavity, they demonstrated the formation of spatially localized, entangled plasmon condensates in 100 nm layer of organic TDAF molecules at room temperature in a disordered system
- ✓ Quoting: “Microcavity is identical to that of Ref. [2]. It uses 9 dielectric mirror pairs on opposite sides of a layer of 2,7-bis[9,9-di(4-methylphenyl)-fluoren-2-yl]-9,9-di(4-methylphenyl)fluorene (TDAF) and was impulsively pumped high above the polariton energy (i.e. nonresonantly).”
- ✓ Created plasmon condensates have spatial dimensions that seem to max-out at diameters of ~100 μ ; beyond this critical size limit they destabilize
- ✓ First-order temporal coherence of condensates = 0.8 picoseconds (ps); this is in reasonable agreement with coherence decay time estimate of 1 ps which is calculated from the observed emission linewidth

Daskalakis *et al*. publish a key paper in *Phys. Rev. Lett*.

Demonstrate formation of organic plasmon condensate at room temp

Surface plasmons in Widom-Larsen theory LENR-active site behave like condensate

EurekAlert! The Global Source for Science News | AAAS

PUBLIC RELEASE: 14-JUL-2015

World first: Significant development in the understanding of macroscopic quantum behavior

Researchers from Polytechnique Montréal and Imperial College London demonstrate the wavelike quantum behavior of a polariton condensate on a macroscopic scale and at room temperature

POLYTECHNIQUE MONTRÉAL

For the first time, the wavelike behaviour of a room-temperature polariton condensate has been demonstrated in the laboratory on a macroscopic length scale. This significant development in the understanding and manipulation of quantum objects is the outcome of a collaboration between Professor Stéphane Kéna-Cohen of Polytechnique Montréal, Professor Stefan Maier and research associate Konstantinos Daskalakis of Imperial College London. Their work has been published in the prestigious journal *Physical Review Letters*.

http://www.eurekalert.org/pub_releases/2015-07/pm-wfs071415.php

Daskalakis *et al.*'s observations effectively support two key ideas in the Widom-Larsen theory's concept of a many-body LENR active site: (1) maximum size of sites is ~100 microns; (2) surface plasmon electrons within such sites are quantum mechanically entangled, i.e. they are coherently and collectively oscillating at ambient temperatures

Daskalakis *et al*. plasmon condensate created in microcavity

Note abundant aromatic rings in TDAF molecule; system is laser-pumped

Microcavity with TDAF layer | **TDAF molecule** | **$g^{(1)}(-r,r)$ for increasing pump fluence**

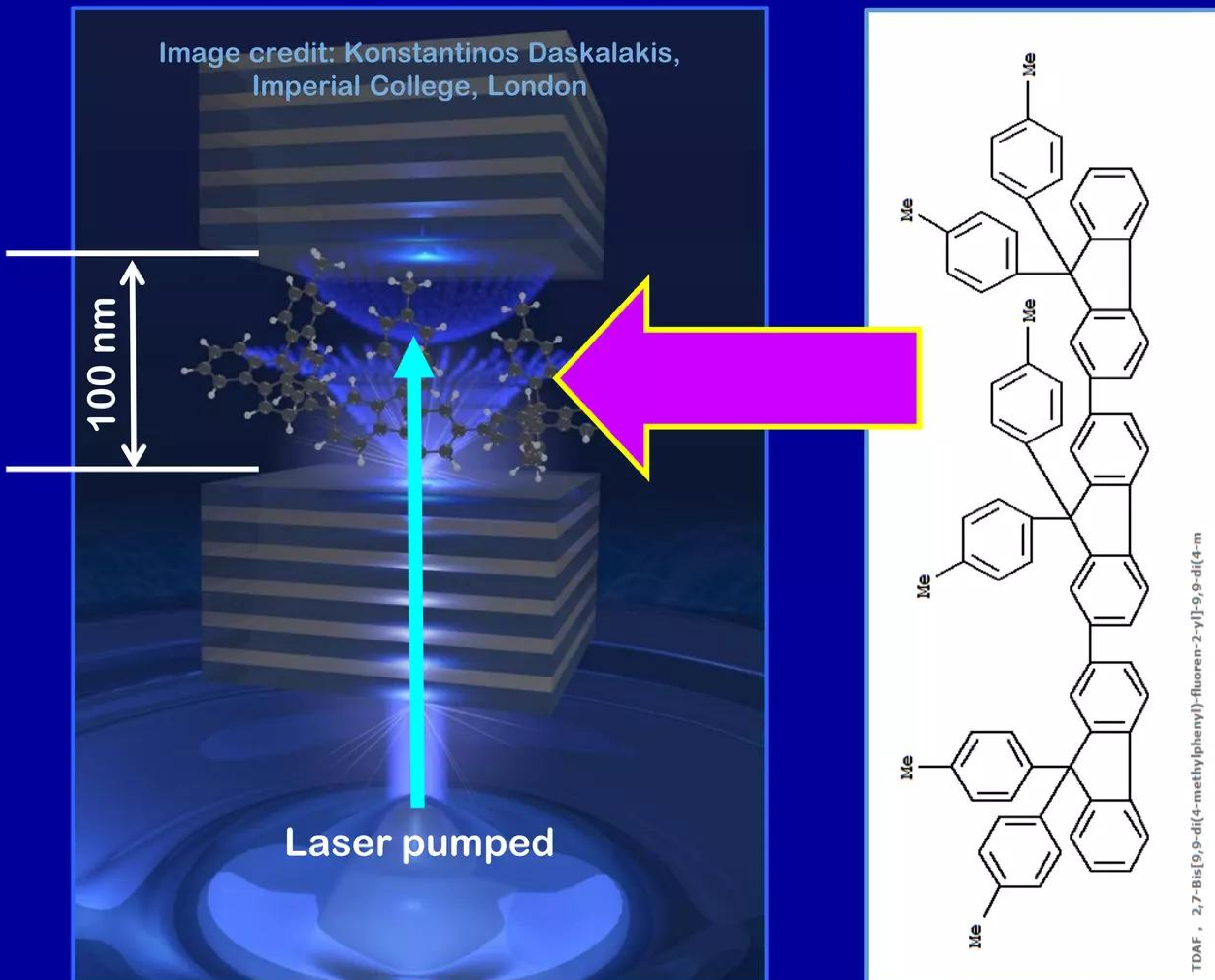
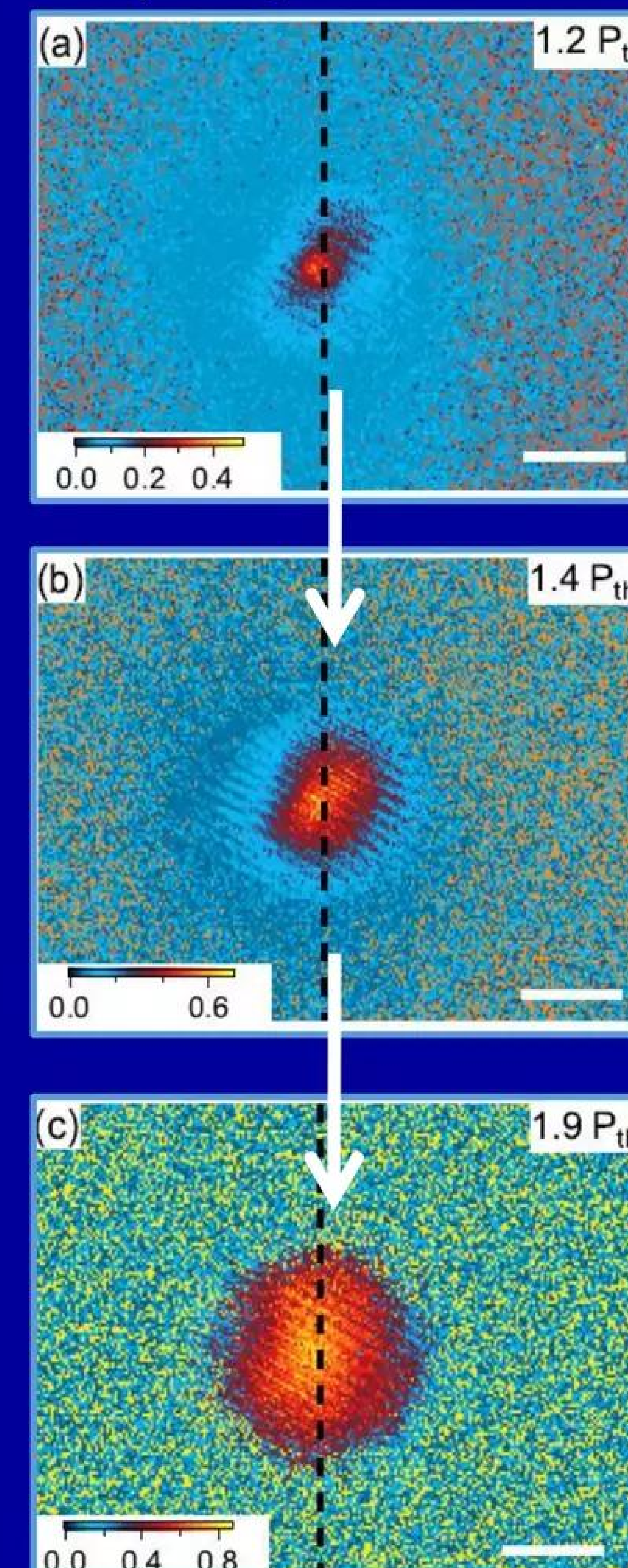


Figure has been adapted by Lattice | Aromatic rings in TDAF



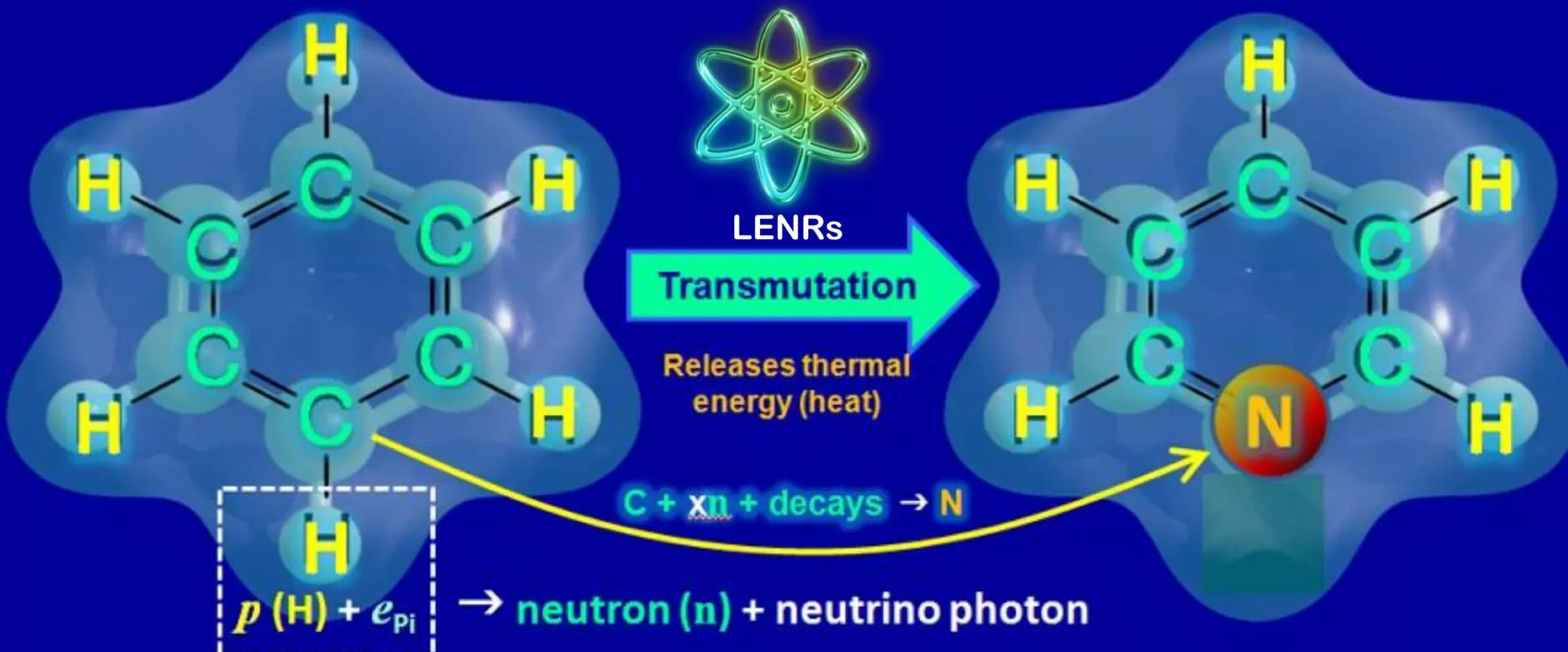
Adapted by Lattice

Radiation-free transmutation of Carbon → Nitrogen → Oxygen

Aromatic ring protons (Hydrogens) converted into low-energy neutrons

Neutrons can be captured by ring Carbon or Hydrogen atoms and transmuted

Summarizes process of the LENR transmutation of Carbon → Nitrogen



For a detailed technical discussion about this topic see Lattice document:

http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewpahs-and-lenrsnov-25-2009

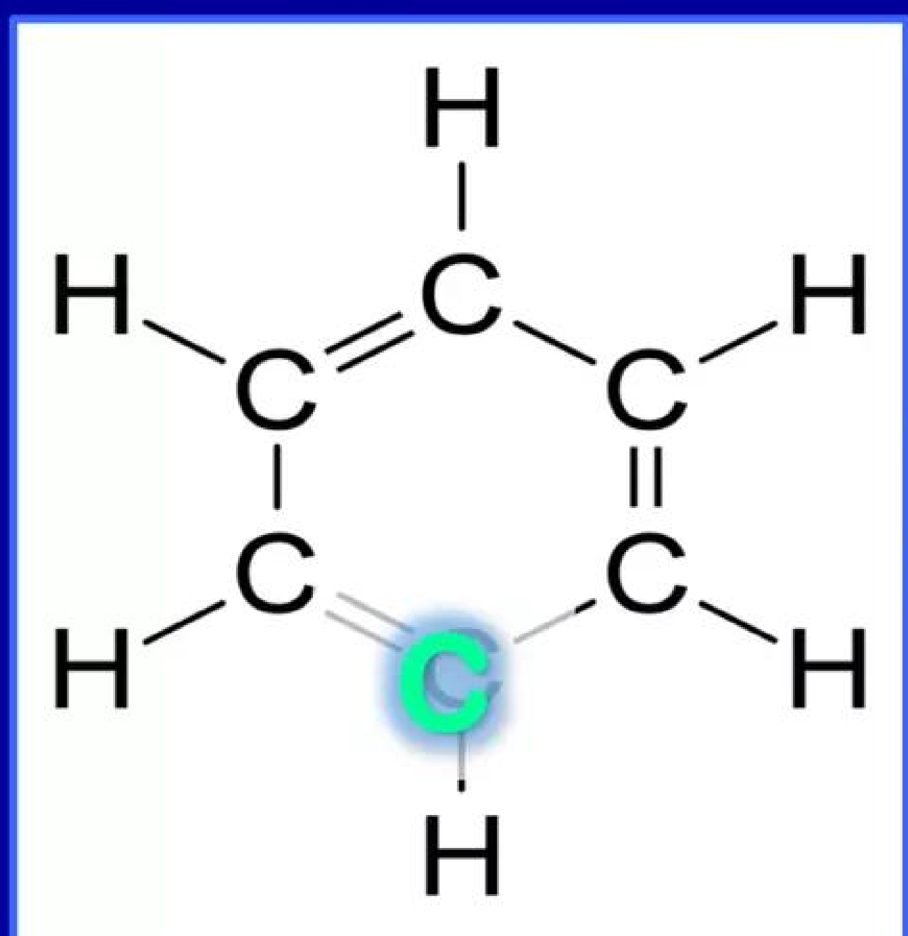
Radiation-free transmutation of Carbon → Nitrogen → Oxygen

Equivalent to CNO cycle of stars but doesn't require star-like conditions

Heat from transmutation reactions break chemical bonds & release products

LENRs interoperate with chemical reactions on condensed matter surfaces

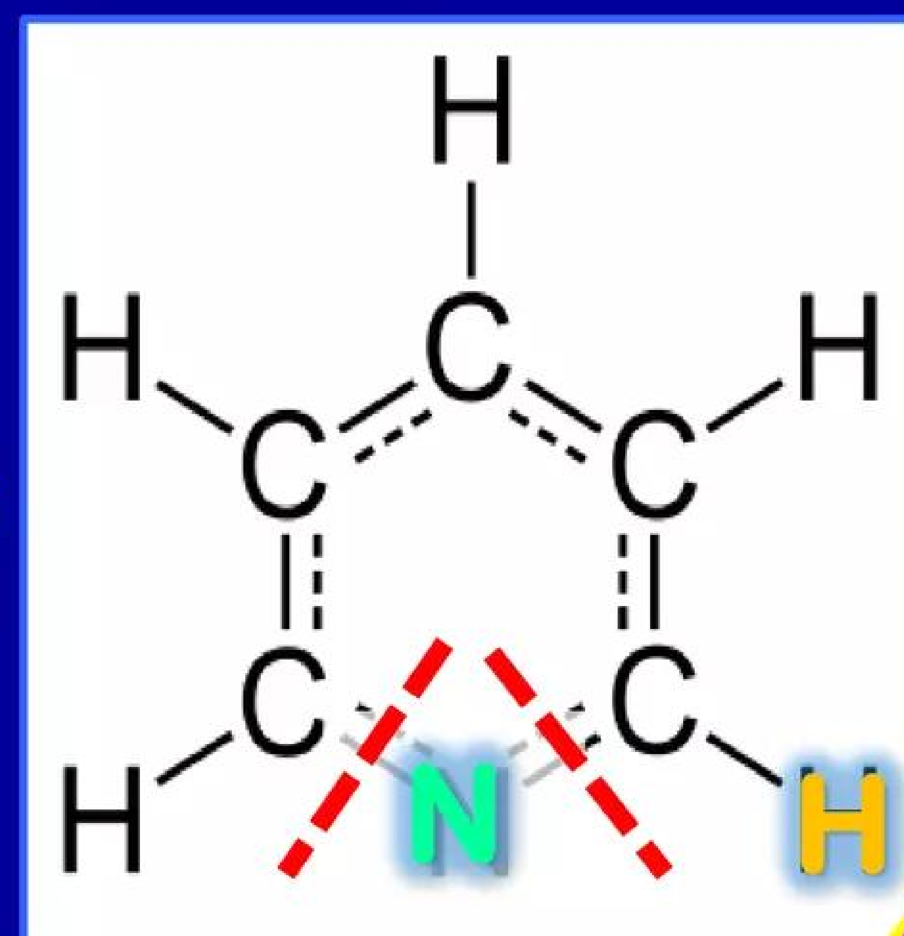
Benzene



Carbon atom on aromatic ring transmuted to Nitrogen via LENR

→

Pyridine (short-lived)



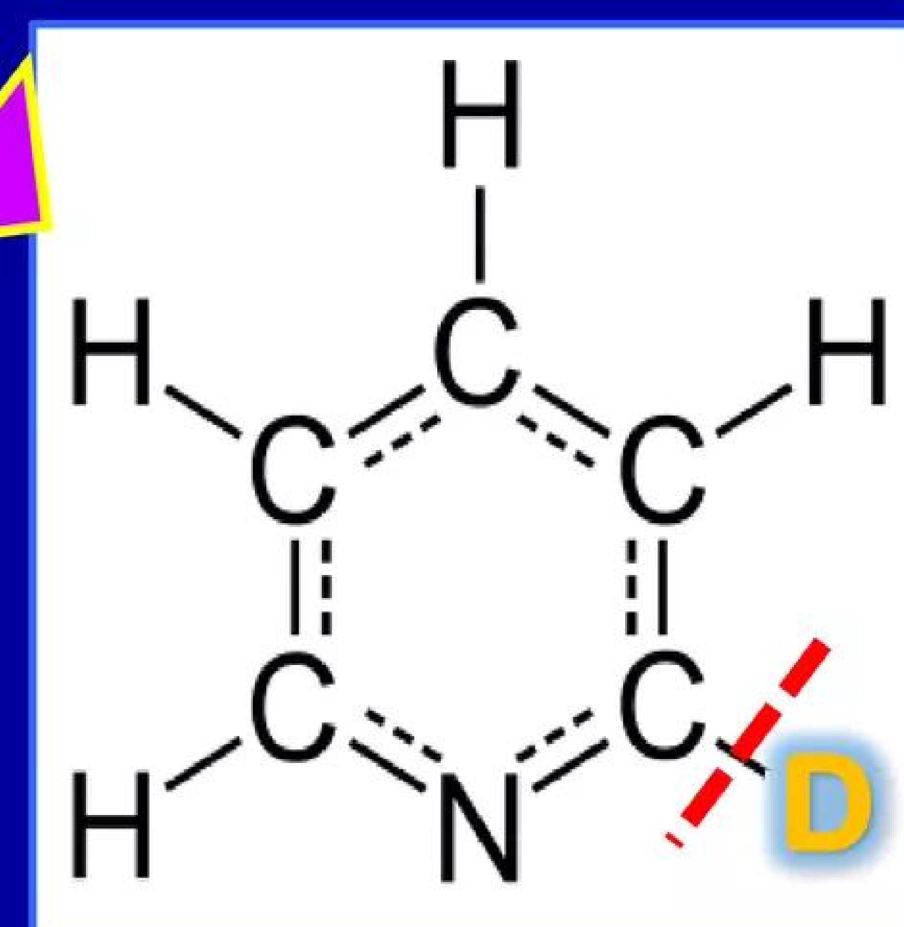
Intense heat on LENR-active molecule breaks chemical bonds

Atomic Nitrogen produced from PAH molecule

→ N^+ → $N^+ + N^+$ → N_2

Nitrogen ions recombine

Nitrogen detected via mass spectroscopy in Mizuno experiment



→ D^+

If Carbon on an aromatic ring captures neutrons it can be transmuted to Nitrogen; on the other hand, if a ring Hydrogen captures neutron it can be transmuted to Deuterium, which is presently thought to be only a Big Bang primordial element

LENRs initiated at modest temperatures and pressures

Metallic reactor vessels function as resonant electromagnetic cavities

Input energy to make neutrons from pressure & E-M radiation emitted from walls

- ✓ Walls of gas-filled metallic or glass LENR reactor vessels can emit various wavelengths of E-M photon radiation energy into the interior space; glass tubes with inside surfaces coated with complex phosphors can also effectively function as resonant E-M cavities
- ✓ Target nanostructures, nanoparticles, and/or aromatic molecules located anywhere in open interior cavities in such reactors can absorb IR, UV, or visible photons radiated from vessel walls if their absorption bands happen (or are engineered) to fall in same resonant spectral range as E-M cavity wall radiation emissions
- ✓ Complex two-way E-M energy transfers occur between interior targets and vessel walls (imagine interior as arrays of E-M nanoantennas located in walls and on targets intercommunicating via send/receive channels)
- ✓ In 2008, T. Mizuno transmuted Carbon into Nitrogen and Oxygen inside of two types of Hydrogen-filled stainless steel reactor vessels at 650º C and ~37 atm H_2 pressure

Hydrogen gas-filled Inconel 625 stainless steel reactor vessel

Mizuno experiments: LENR CNO cycle Hokkaido Univ. (2008)

Used H_2 + pressure, temperature, time to transmute Carbon into N and O

Carbon in form of Phenanthrene molecule - a polycyclic aromatic hydrocarbon

Schematic diagram of Mizuno's experimental setup with two different reactor vessels

In context of Widom-Larsen theory reactor vessel functions as resonant electromagnetic cavity

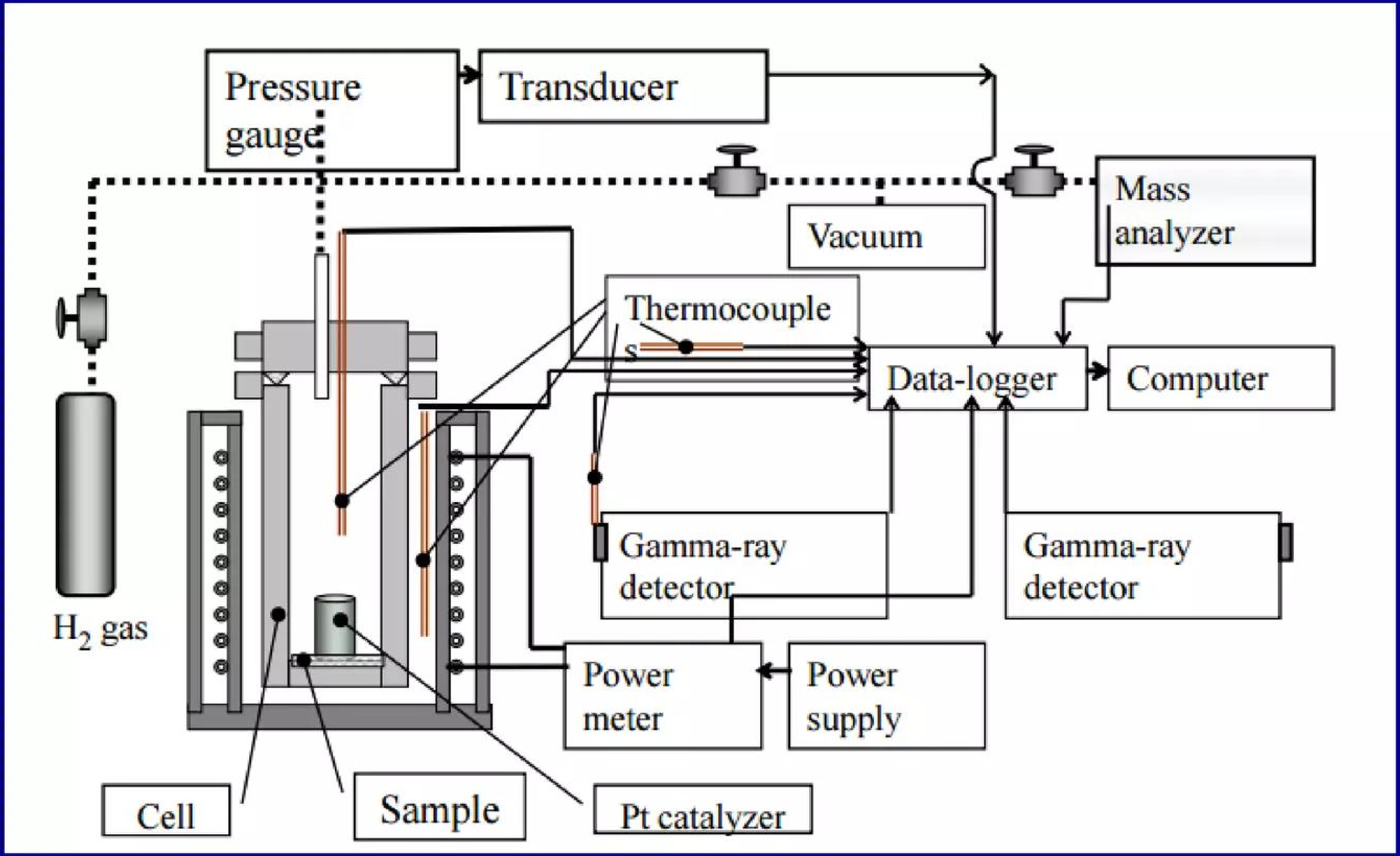


Photo of both reactor vessels

Stainless steel

Source: T. Mizuno, ICCF-15 conference presentation, Frascati, Italy October 2009

http://iccf15.frascati.enea.it/ICCF15-PRESENTATIONS/S7_O8_Mizuno.pdf

Mizuno's experiments with Phenanthrene, Platinum, and H_2

Transmutation occurred at temperatures < 700° C and pressures < 60 atm

- ✓ Solid Phenanthrene (1 gram - 99.5% pure) and Platinum (Pt) "catalyzer" (5 cm x 10 cm rectangular mesh weighing ~27.8 gms - 99.99% pure) were both placed into a metallic reactor vessel; its top lid was then bolted shut
- ✓ Reactor vessel then connected to a vacuum system; pumped down to ~10^{-3} mm/Hg
- ✓ Hydrogen gas 99.99% pure: impurities in ppm were O_2 = 5; N_2 = 50; CO = 1; CO_2 = 21; hydrocarbons <1) was then admitted into the reactor vessel (Inconel 625 is 56 mm OD, 26 mm ID, 160 mm in length, 0.1 L volume, rated for 500 atm; SUS 316L vessel is 15 mm OD, 9 mm ID, 300 mm in length, 0.02 L volume, rated for < 200 atm) – experimental H_2 pressures ranged from 37 - 60 atm
- ✓ After filling with 99+% pure hydrogen, Inconel 625 or SUS 316L reactor vessel was heated with 2 kW electric furnace; maximum temperature reached was ~700° C
- ✓ Inconel 625 contains approximately: 58% Ni; 20 - 23% Cr; 5% Fe; as well as 8 - 10% Mo; 3.15 - 4.15% Nb; 1% Co; 0.5% Mn; 0.4% Al; 0.4% Ti; 0.5% Si; 0.1% C; 0.015% S; and 0.015% P --- SUS 316L contains maximum of approximately: 0.03% C; 2.0% Mn; 0.75% Si; 0.045% P; 0.045% S; 16 - 18% Cr; 2 - 3% Mo; and 10 - 14% Ni
- ✓ Reactor vessel was then allowed to 'cook' at various temperatures for varying periods that ranged up to ~10 days. During that time, heat production and radiation were monitored. At the end of a given experiment, gas and residues remaining in the metallic reactor vessel were analyzed with sensitive mass spectroscopy

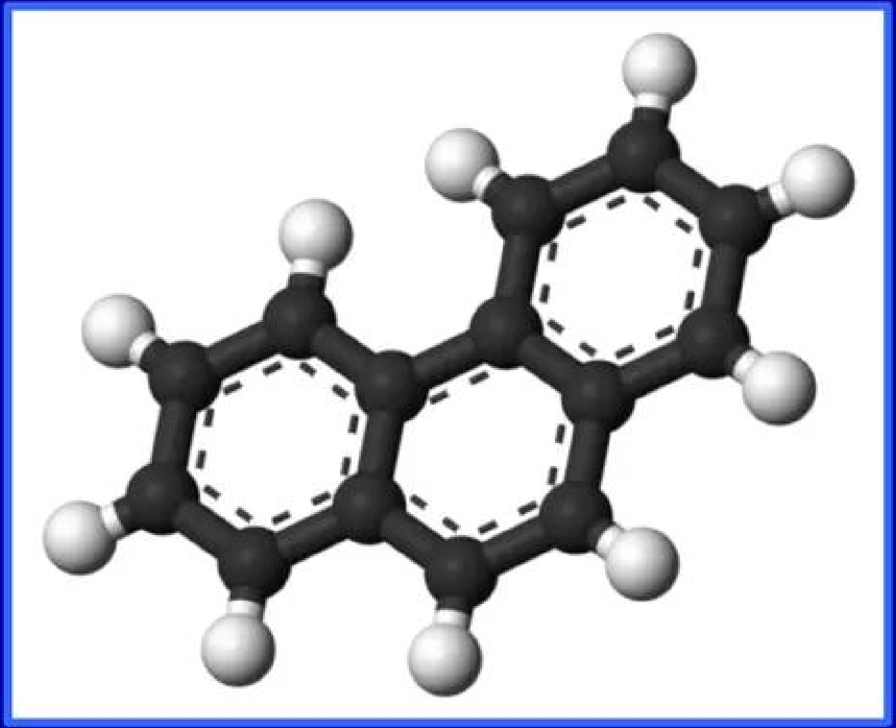
Overview of various parameters in Mizuno LENR experiments

Hydrogenation of Phenanthrene can be accompanied by transmutation

Table 1. Cell conditions for the five runs shown in Fig. 20

		Reaction Cell Conditions		
Cell Status or Contents	Symbol	Pressure (atm)	Temperature (°C)	Gas Volume (L)
Excess heat made	● (red)	37	650	0.33
No excess heat	● (blue)	60	605	0.56
No Pt catalyst	▲	54	645	0.48
No phenanthrene	◆	38	660	0.33
No H_2 gas	□	0.33	350	0.004

Credit: T. Mizuno



Phenanthrene is member of large family of C-H organic molecules called polycyclic aromatic hydrocarbons (PAHs); they are distinguished by having from two up to ten 6-carbon aromatic (benzene-like) rings bonded along their edges

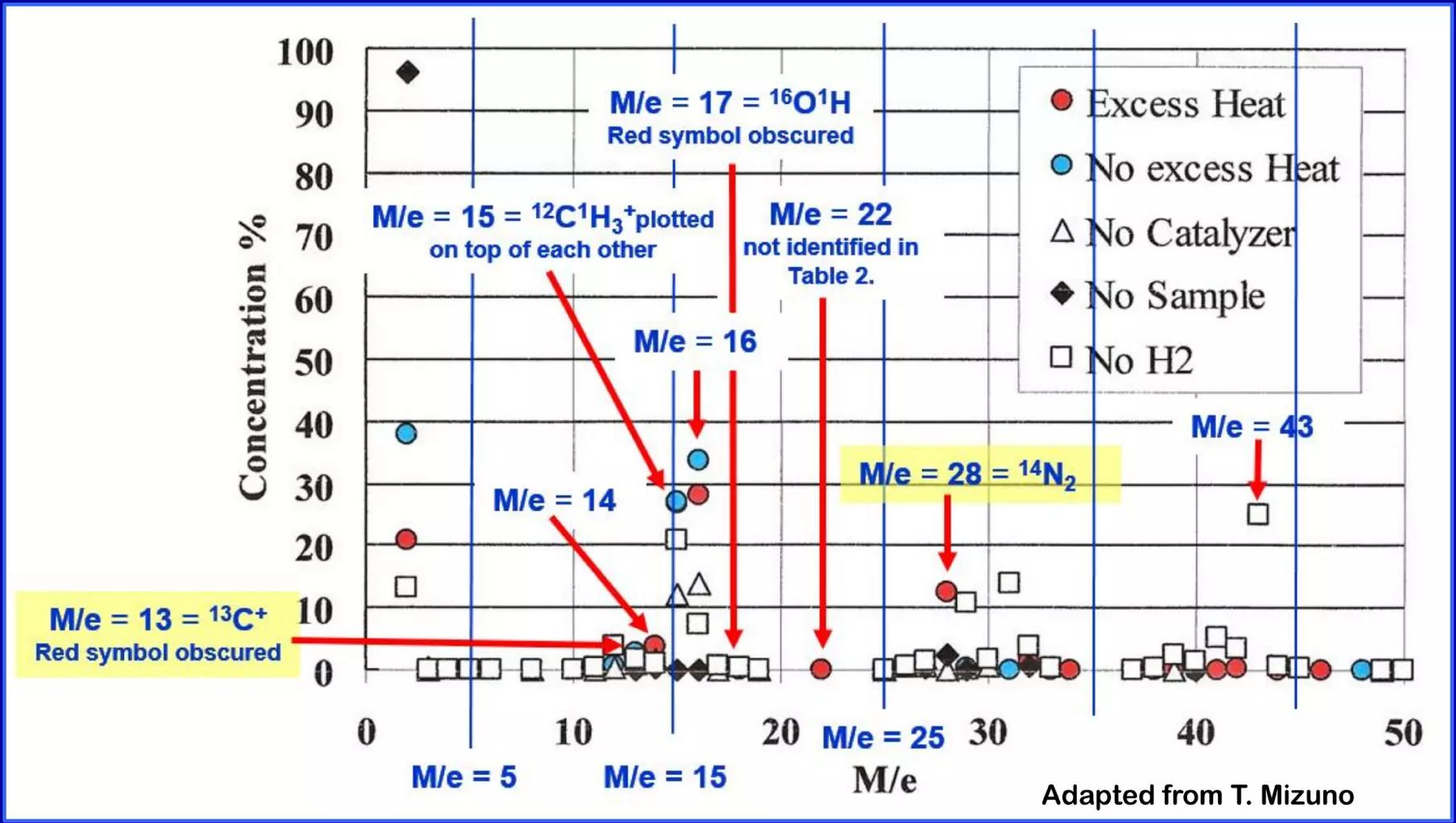
For technical discussion see Lattice document:

http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewpahs-and-lenrsnov-25-2009

Results of mass spectroscopy analyses post-experiments

Significant amounts of Carbon-13 (^{13}C) and Nitrogen (^{14}N) were detected

Stable Carbon-13 and Nitrogen-14 produced by neutrons capturing on Carbon-12



Discussion about Mizuno's mass spectroscopy analyses

Nitrogen seen is unlikely to be contaminant for number of good reasons

Some experiments created substantial amounts of rare ^{13}C (nat. abundance 1.3%)

Table 2. Percent of each species found for the five runs shown in Fig. 20 — Adapted from T. Mizuno

Mass/ charge ratio (m/e)	Likely species [Mizuno]	Larsen comments –alternative interpretations/questions All of these singly-ionized species have same m/e ratio (see note re resolution below)	Percent of all gas				
			Excess heat produced	No excess heat observed	No Pt catalyst in metallic reaction cell	No $^{12}C_{14}{}^{1}H_{10}$ phenanthrene in reaction cell	No $^{1}H_2$ gas in metallic reaction cell
2	$^{1}H_2^+$	Same conclusion	21	37	68	96.2	13
12	$^{12}C^+$	Same conclusion	0.7	0.7	0.3	0	3.7
→ 13	$^{13}C^+$	Same conclusion	2.5	2.6	1.0	0	1.8
14	$^{12}C^{1}H_2^+$	$^{13}C^{1}H^+$ [resolution needed = 2916] ?	3.8	1.0	1.6	0.36	1.1
15	$^{12}C^{1}H_3^+$	$^{14}C^{1}H^+$ [1210] ?	27	27	12	0	21
16	$^{12}C^{1}H_4^+$	$^{14}C^{1}H_2^+$ [952], $^{14}N^{1}H_2^+$ [1269], $^{15}N^{1}H^+$ [684] ?	28	34	12	0.1	7.5
→ 17	$^{16}O^{1}H^+$	$^{14}N^{1}H_3^+$ [720] , $^{13}C^{1}H_4$+ [541], $^{15}N^{1}H_2^+$ [1328] ?	0.3	0	0.1	0	0.8
→ 28	$^{14}N_2^+$	$^{1}H^{13}C^{14}N^+$ [3590], $^{12}C^{16}O^+$ [2545] ?	12.5	0	0.1	0.25	0
29	$^{12}C_2{}^{1}H_5^+$	$^{1}H^{13}C^{15}N^+$ [1028], $^{14}N^{15}N^+$ [805], $^{13}C^{16}O^+$ [707] ?	-	-	-	-	11
43	$^{12}C_3{}^{1}H_7^+$	$^{13}C_3{}^{1}H_4^+$ [2986] ?	-	-	-	-	25
		Symbols in Mizuno's previous Fig. 20	●	●	▲	◆	□

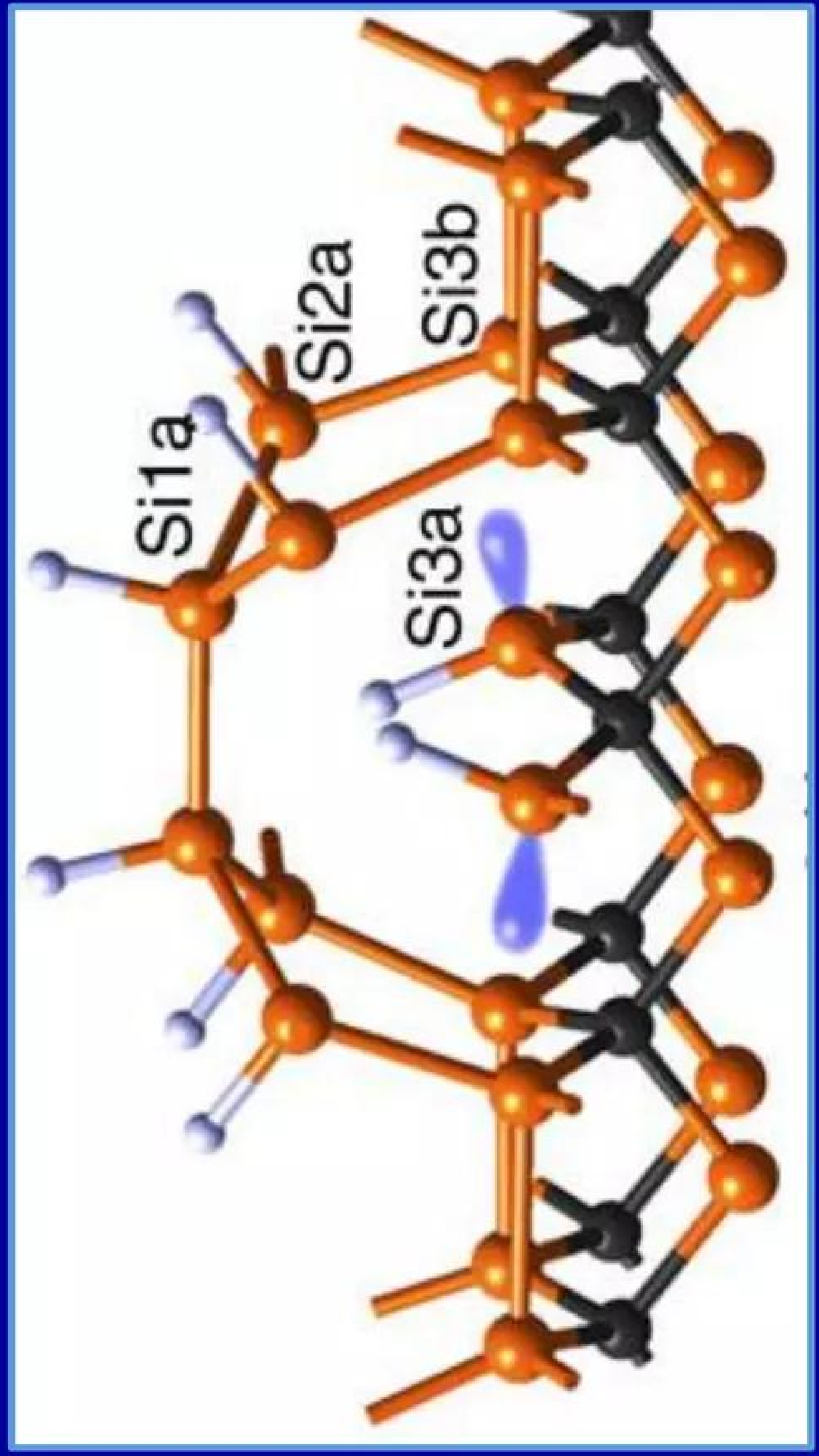
Note: in their paper resolution of mass spec used in analyses listed as "variable, 300, 3000, or 7500." However, actual resolution settings used to collect above data were not specified. Thus, if resolution had been set at 300, none of species listed above with same m/e ratio can be reliably discriminated from each other. If set at 3000, Mizuno's $^{12}C^{1}H_2^+$, $^{14}N_2^+$, and $^{12}C_3{}^{1}H_7^+$ could be mixtures

Silicon carbide (SiC) readily bonds to Hydrogen in molecules

Late-stage red giant stars expel gigatons of SiC into circumstellar space

- ✓ Many-body LENR-active sites that comprise quantum mechanically entangled protons and electrons can form spontaneously on metallic surfaces, at many metal/oxide interfaces, and on Silicon, graphene, and fullerene surfaces
- ✓ Widom-Larsen theory also extends to aromatic rings in which delocalized Hydrogen atoms (protons) and π electrons associated with ring structures can be transformed into LENR-active sites with sufficient proper input energy. This functional behavior further applies to multi-ring polycyclic aromatic hydrocarbons (PAHs) as evidenced in Mizuno's Phenanthrene (3-rings) experiments at Hokkaido University
- ✓ Mizuno experiments demonstrated existence of rough LENR equivalent of stellar CNO cycle that can occur in condensed matter under moderate temperatures/pressures vs. in stars
- ✓ It is now known that PAHs are very commonly present in materials that comprise circumstellar accretion disks throughout the visible Universe. P. Merino *et al.* (*Nature Comm.* 2013) believe PAHs are synthesized on surfaces of Hydrogen-rich SiC grains bathed in ultraviolet (UV) photon radiation emitted from stars. We argue that LENRs can occur at low rates on dust grains present in the same environments

H/3C-SiC(100)-3 × 2 surface



Credit: P. Soukiassian *et al.*
Fig. 1 in *Nature Comm.* (2013)

PAHs comprise 20% of Carbon in photodissociation regions

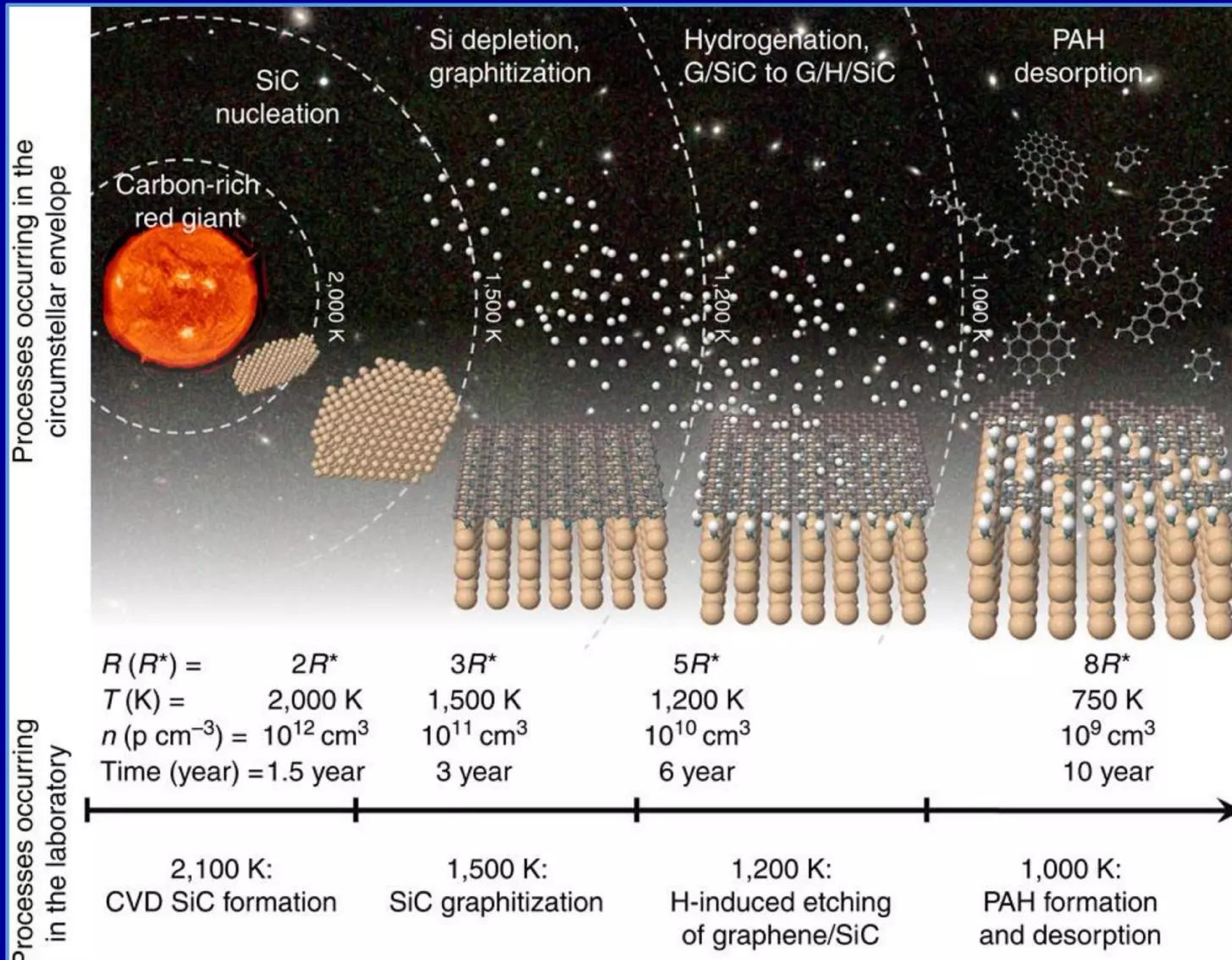
Near-ubiquitous and present wherever materials bathed with UV radiation

Credit: NASA/JPL-Caltech/T. Pyle

"Hydrogen-induced nanotunnel opening within semiconductor subsurface" P. Soukiassian *et al.* *Nature Communications* **4** article #2800 (2013)
http://www.nature.com/ncomms/2013/131121/ncomms3800/full/ncomms3800.html

Dust grain surfaces catalyze synthesis of ubiquitous PAHs

"Graphene etching on SiC grains as a path to interstellar PAH formation"

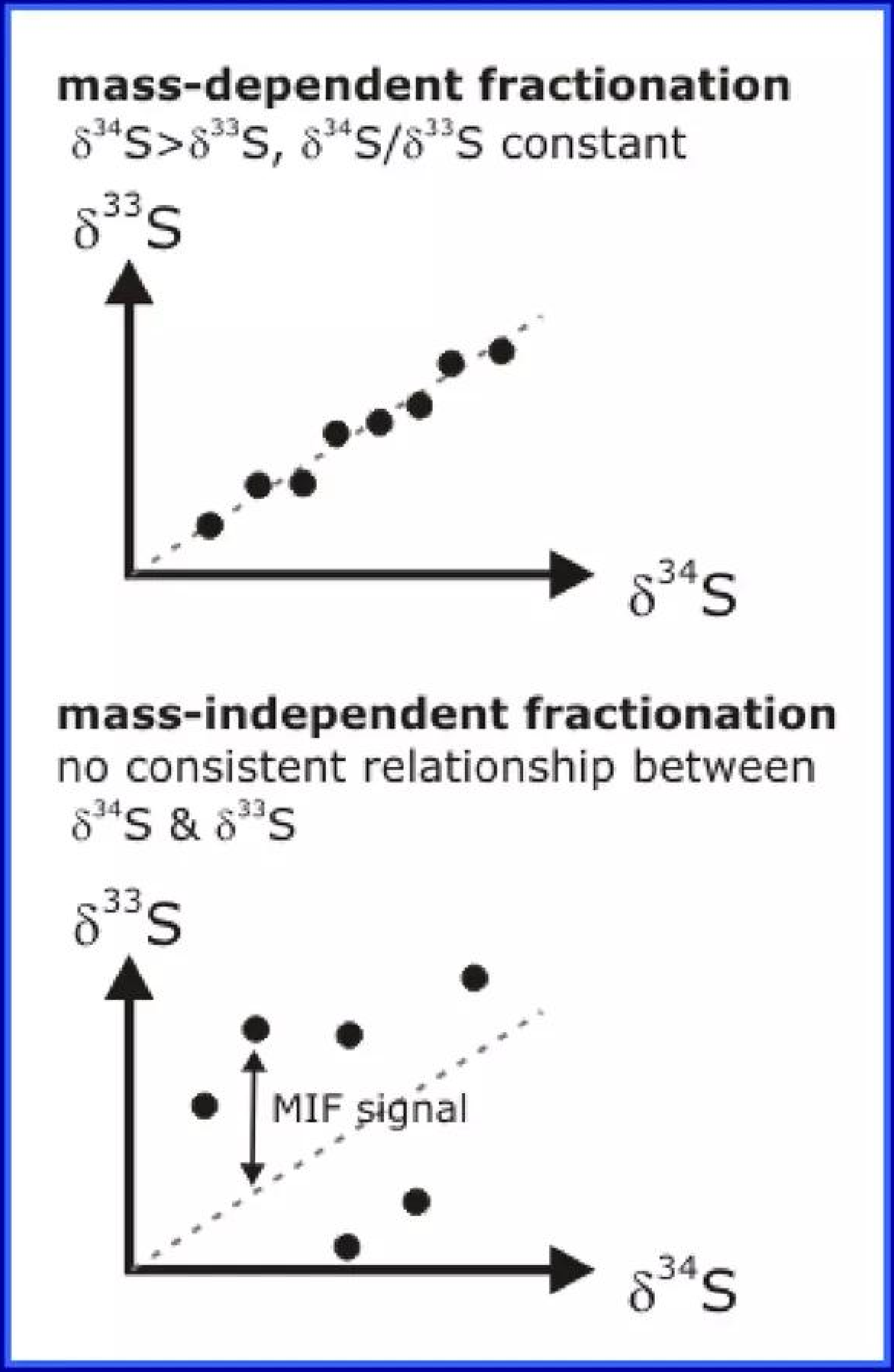


http://www.nature.com/ncomms/2014/140121/ncomms4054/fig_tab/ncomms4054_F1.html

LENR processes can mimic effects of chemical fractionation

Theoretical chemists assume no nucleosynthesis occurs in their systems

- ✓ For ~ 60 years, a body of theory has been developed and articulated to explain progressively increasing numbers of stable isotope anomalies observed in a vast array of mass spectroscopic data obtained from many different types of natural and experimental, abiological and biological systems. Central ideas in this chemical "fractionation" theory embody equilibrium as well as irreversible, mass-dependent, mass-independent, nuclear field shifts, and more recently "self-shielding" chemical processes claimed to be very able to separate isotopes, thus explaining reported isotopic anomalies
- ✓ Although not explicitly acknowledged by fractionation theorists, an intrinsic bedrock *fundamental* assumption underlying all of this theory and interpretation of data is that nucleosynthetic processes capable of altering stable isotope ratios and/or producing new mixtures of different elements over time have not operated in such systems after the initial creation in stars; ergo, ordinary chemical processes are able to explain everything
- ✓ **If LENRs are occurring in some of these systems, the above-noted fundamental assumption will be violated**



Delta (δ) notation used to describe isotopic abundances

Examples provided for Hydrogen, Carbon, Oxygen, and Nitrogen isotopes

$$\delta = \left(\frac{R_{sample} - R_{standard}}{R_{standard}} \right) \text{ x } 1000$$

$$\delta^{18}O = \left[\frac{(^{18}O/^{16}O)_{sam} - (^{18}O/^{16}O)_{SMOW}}{(^{18}O/^{16}O)_{SMOW}} \right] \times 10^3$$

✓ **Oxygen natural abundance: ^{16}O = 99.759%; ^{17}O = 0.0374%; ^{18}O = 0.2039%**

If ^{16}O were exposed to fluxes of ultralow energy LENR neutrons, it would first be transmuted to ^{17}O with capture of one neutron. Now ^{17}O has highest neutron capture cross-section of three stable Oxygen isotopes (^{17}O = 0.54 millibarns for neutrons at thermal energies which is 2.8x > ^{16}O and 3.4x >^{18}O), so $^{17}O + n \rightarrow {}^{18}O$ is very likely

Oxygen is an unusual lighter element in that ^{17}O just happens to have a significant cross-section for alpha decay upon capturing a neutron. Therefore, ^{17}O can be depleted in two ways by neutron-catalyzed LENR processes: (1.) neutron capture to ^{18}O; and (2.) alpha (^4He) decay to Carbon-14 (^{14}C). Those two competing processes are probably the reason why ^{17}O has a lower natural abundance than ^{16}O and ^{18}O

All other things being equal, repeated or protracted exposure of Oxygen atoms to ultralow energy LENR neutrons could significantly increase the value of $\delta^{18}O$

Examples of shifts in δ value after capturing LENR neutrons

- ✓ **Hydrogen natural abundance: ^{1}H = 99.985%; ^{2}H (D; deuterium) = 0.015%**

  ^{1}H has substantial capture cross-section for neutrons, 0.332 barns at thermal energies note (H is 1/v isotope); this is ~650x > than the neutron capture cross-section for Deuterium (^{2}H) and >50,000x that for Tritium (^{3}H). In condensed matter LENR systems, $^{1}H + n \rightarrow {}^{2}H + \gamma$ the ~2.2 MeV gamma photon produced by ULM neutron capture on ^{1}H is directly converted to infrared (IR) photons by local heavy electrons. Thus, no hard MeV-energy gamma radiation emission would be detected. This capture reaction increases $\delta\,^{2}H$

- ✓ **Carbon natural abundance: ^{12}C = 98.93%; ^{13}C = 1.07%**

  At thermal energies, ^{12}C has a neutron capture cross-section of ~3.5 millibarns; at ULM neutron energies it is estimated to be > 3,000 barns because ^{12}C is a 1/v isotope. Thus, in LENR condensed matter systems the reaction $^{12}C + n \rightarrow {}^{13}C + \gamma$ could in theory occur at substantial rates; capture gammas would not be detected because of local conversion to IR by heavy-mass electrons; at low neutron fluxes reaction would tend to increase $\delta^{13}C$

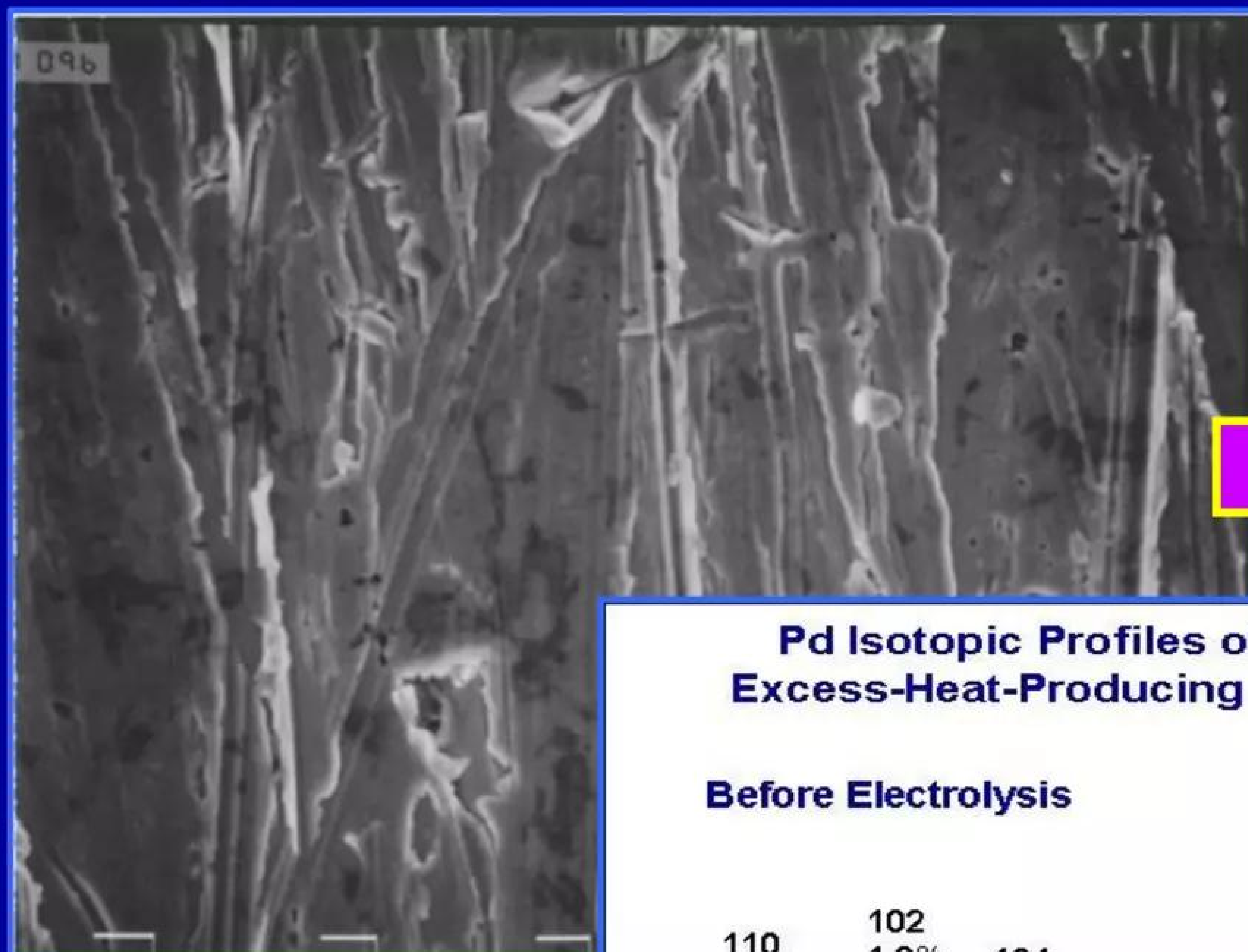
- ✓ **Nitrogen natural abundance: ^{14}N = 99.632%; ^{15}N = 0.368%**

  At thermal energies, ^{14}N has a neutron capture cross-section of 0.080 barns; at ULM energies it may be 10^{5}-10^{6} larger because ^{14}N is 1/v isotope. Thus, in LENR systems the reaction $^{14}N + n \rightarrow {}^{15}N + \gamma$ can potentially occur at significant rates; again, capture gammas would not be detected because of conversion to IR by heavy electrons. LENR neutron capture on ^{15}N would produce ^{16}N which is unstable (half-life = 7.1 seconds) and beta decays into ^{16}O which is stable. Thermal neutron capture cross-section for ^{15}N is 2,000x less than ^{14}N; all other things being equal, at low ULM neutron fluxes ^{15}N should 'pile-up' faster than it can be transmuted via neutron capture into ^{16}N; altogether, these neutron capture reactions would likely tend to produce increases in $\delta^{15}N$

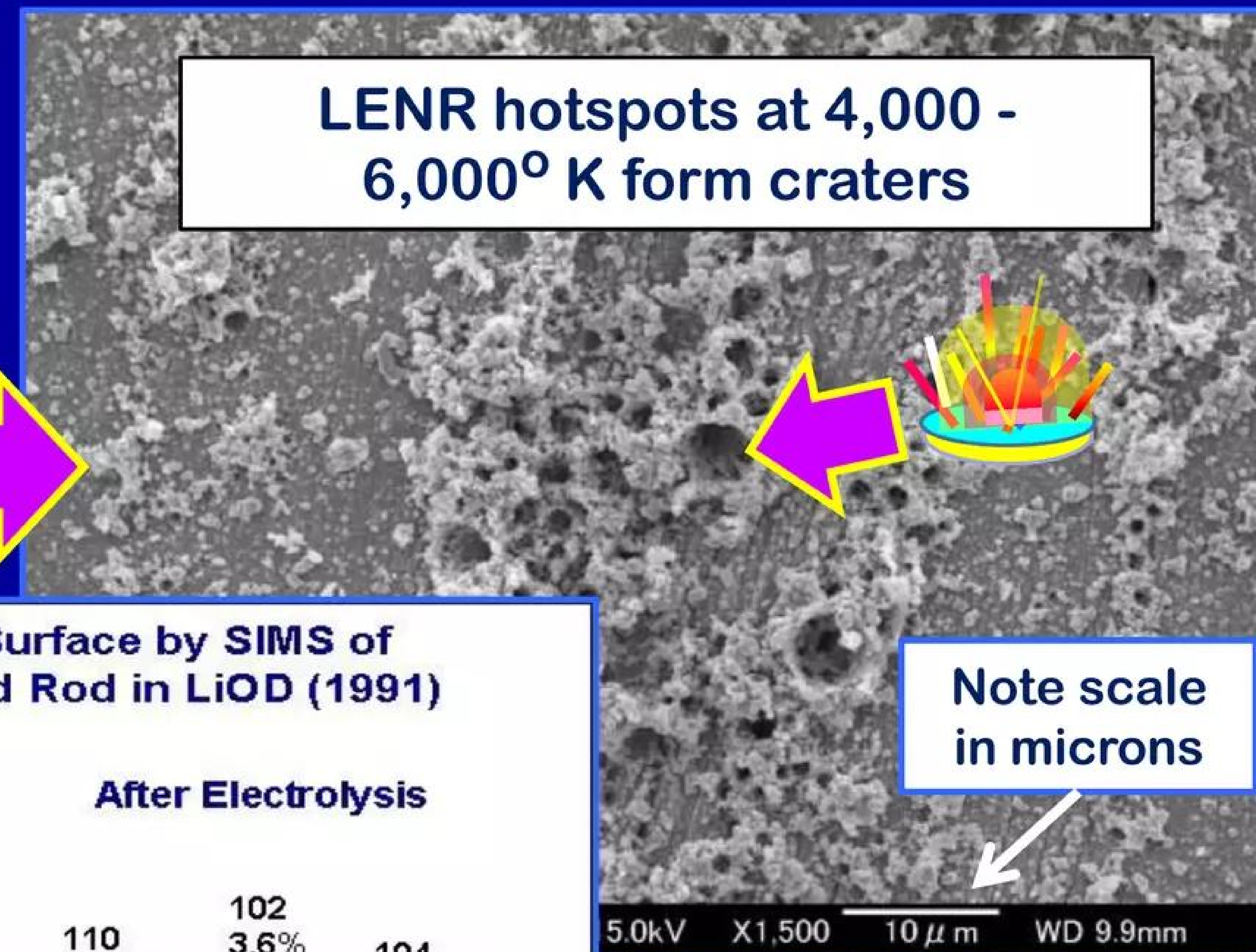
Isotopic ratios of Palladium are shifted in electrolytic cells

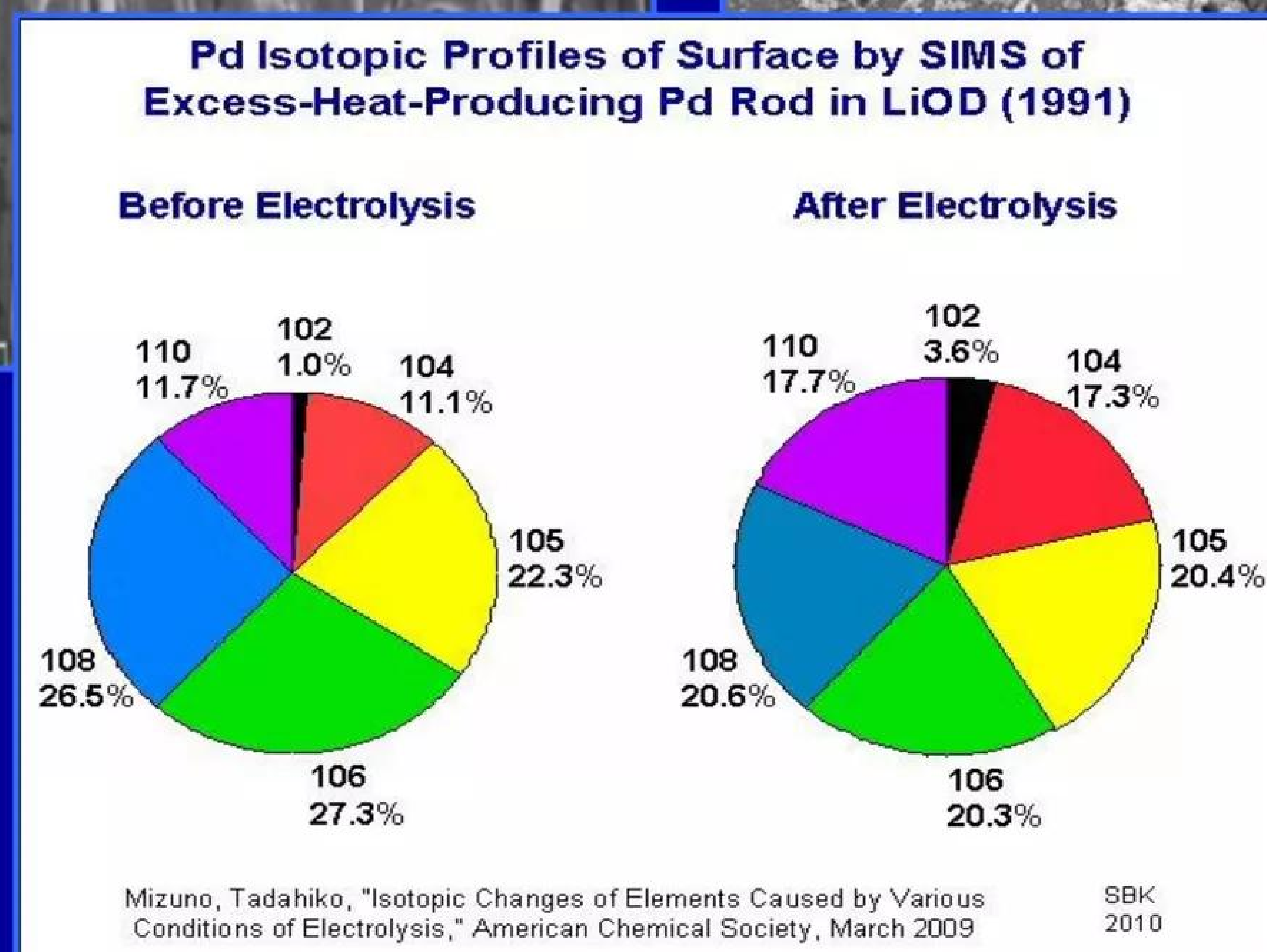
Mizuno et al. (2012) reported major changes in Palladium (Pd) isotopes

Before: relatively smooth surface



After: rugged terrain with μm-scale craters





Source: ICCF-17 conference (2012) T. Mizuno *et al.*

Quoting: "These photo are the Pd electrode before and after the electrolysis. Electrolysis was conducted for a long time, several day or several week. Typical current density was 20mA/cm^2. Here, you see the metal particle (100 nm or less) on the surface after electrolysis. Some of them are less than 10 nano-meter of size."

Graphic: New Energy Times

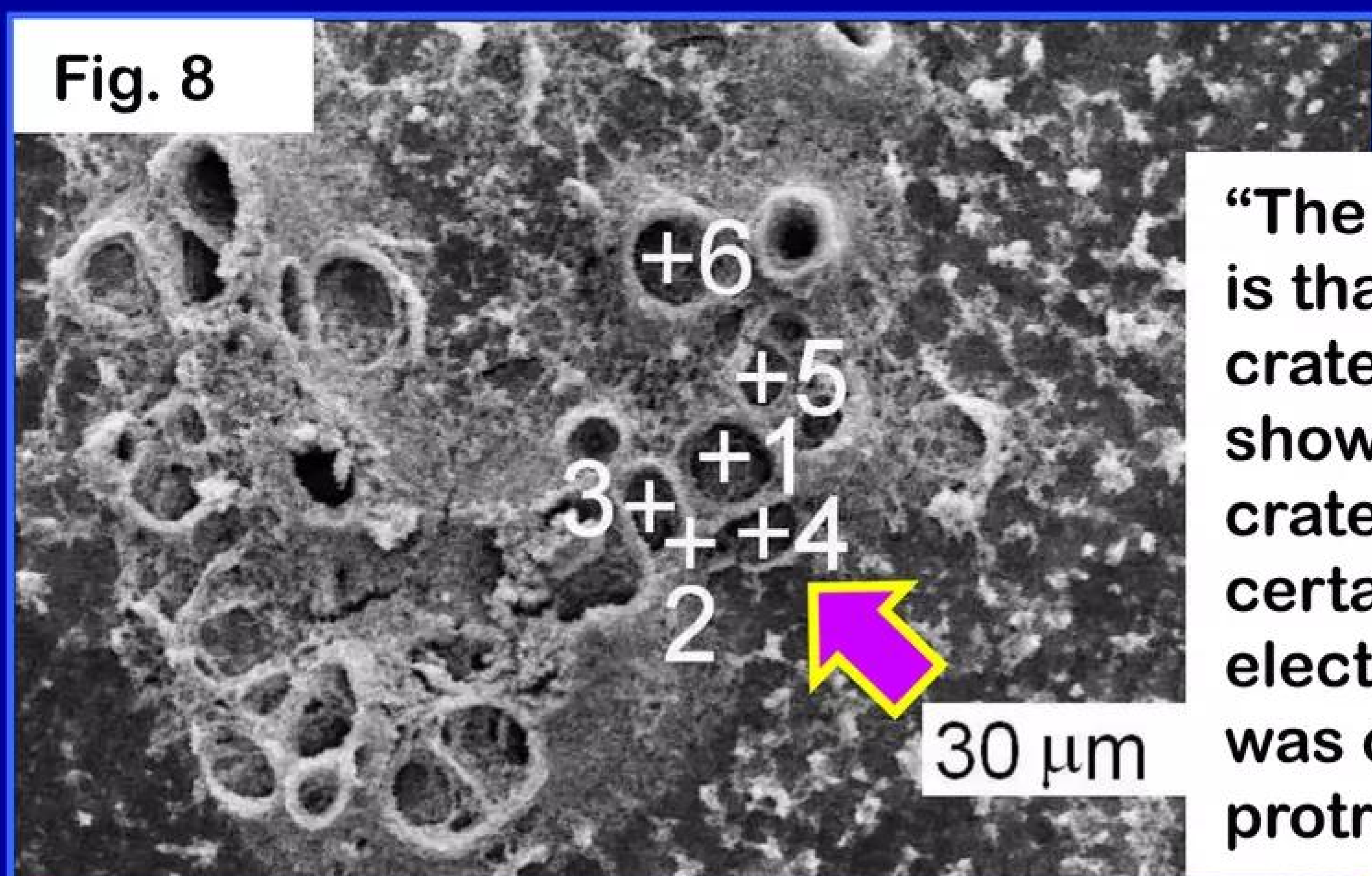
LENRs create heterogeneous mix of elements on surfaces

Zhang & Dash(2007) transmuted Palladium (Pd) into Silver (Ag)

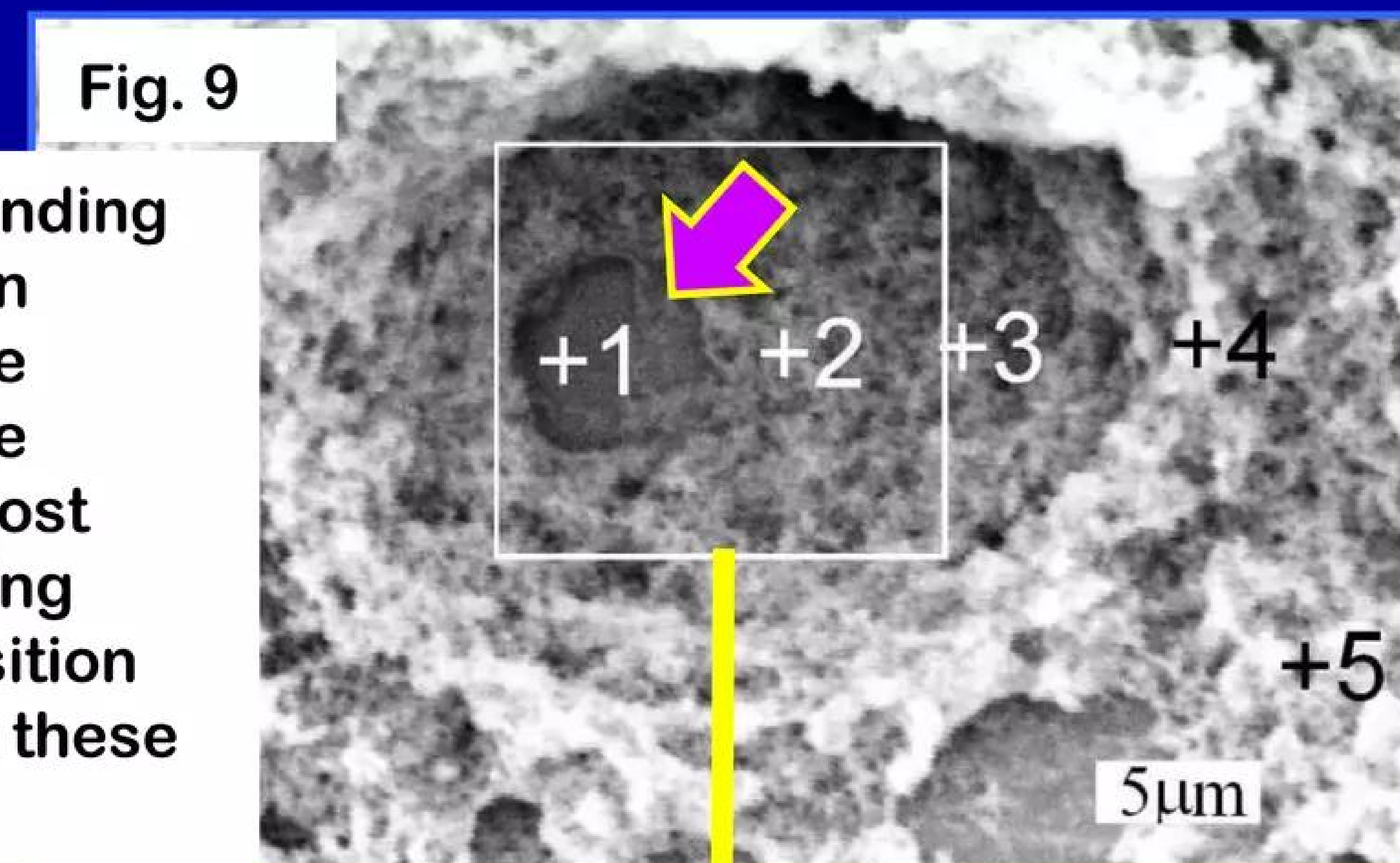
These reactions explain nucleosynthesis of Silver in experiments

Pd + *n* → [unstable neutron-rich Pd isotopes] → Ag [two stable Silver isotopes]

Pd cathode surface - Zhang & Dash (2007) - Figs. 8 and 9



"The most common finding is that Silver occurs in craters, such as those shown in Fig. 8. These craters with rims almost certainly formed during electrolysis. Pt deposition was concentrated on these protruding rims."



http://www.lenr-canr.org/acrobat/ZhangWSexcessheat.pdf

Zhang & Dash: Table IX. Relative atomic percent concentrations of Silver (Ag) in area and spots shown in Fig. 9

Spot #	wa*	area**	+1	+2	+3	+4	+5
Ag/(Pd+Ag)	1.2 +/- 0.5	5.6 +/- 0.4	6.8 +/- 0.4	5.6 +/- 0.3	6.3 +/- 0.4	3.6 +/- 0.6	1.2 +/- 0.5

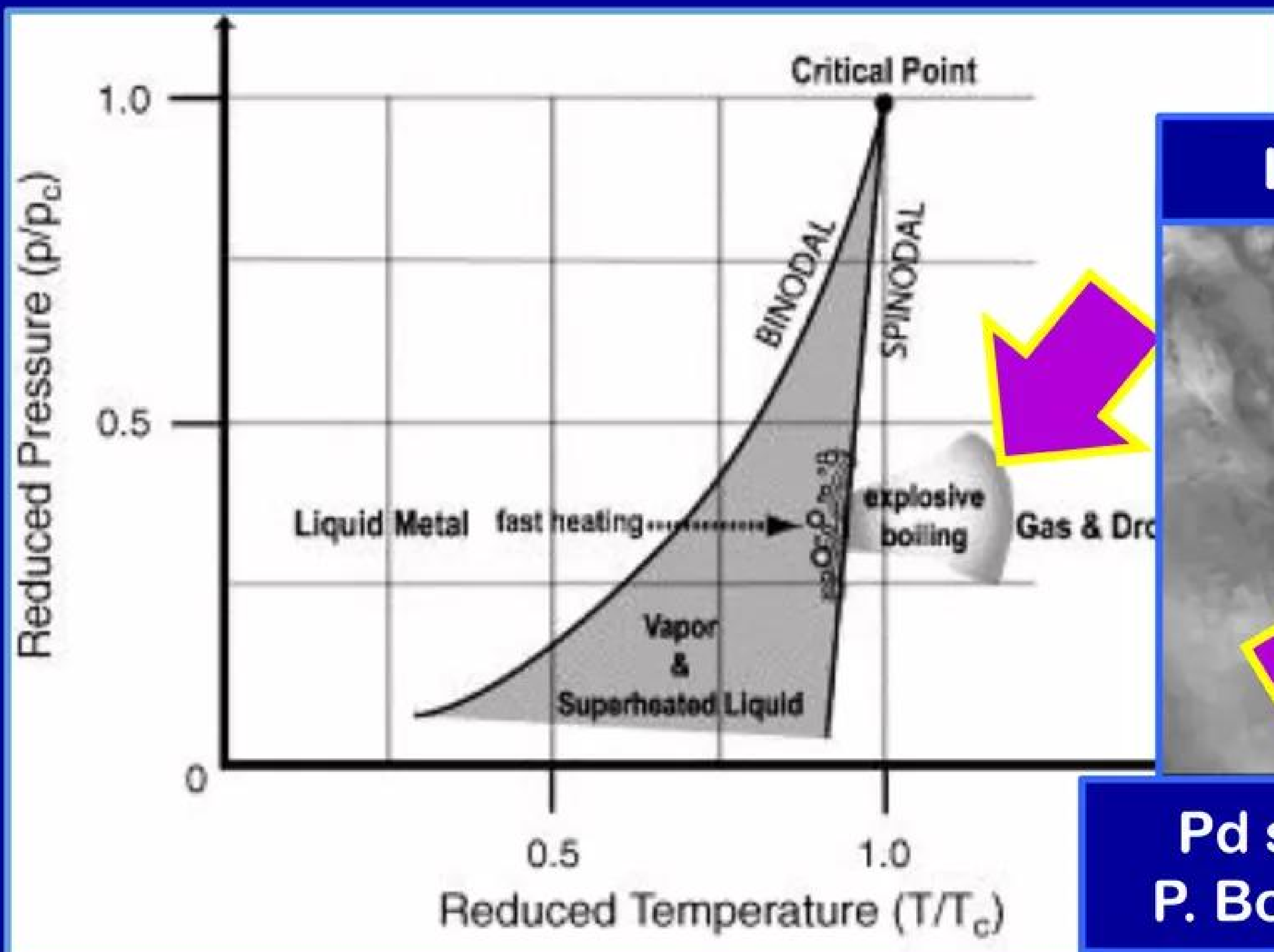
*wa = whole entire area comprising image in Fig. 9

** area = delimited by the white square outlined in Fig. 9

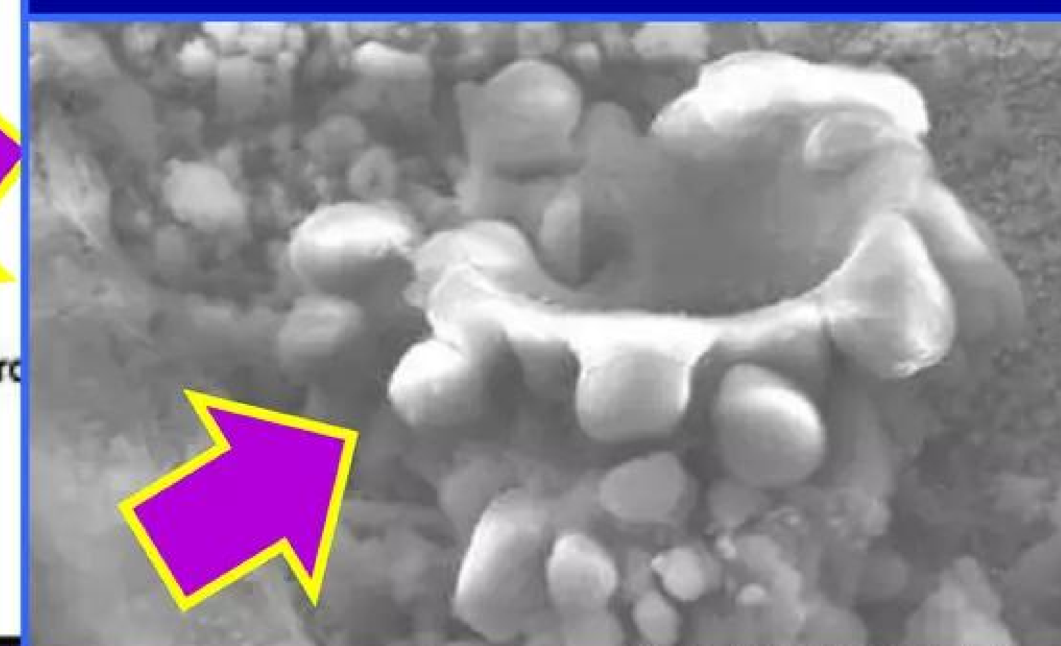
Pd boiling point = 2,970^{o} C

LENR-active sites can create explosively released droplets

Cooled droplets could become dust grains containing isotopic anomalies



LENR crater on Palladium



Pd surface post-experiment SEM
P. Boss *et al.* , U.S. Navy - SPAWAR

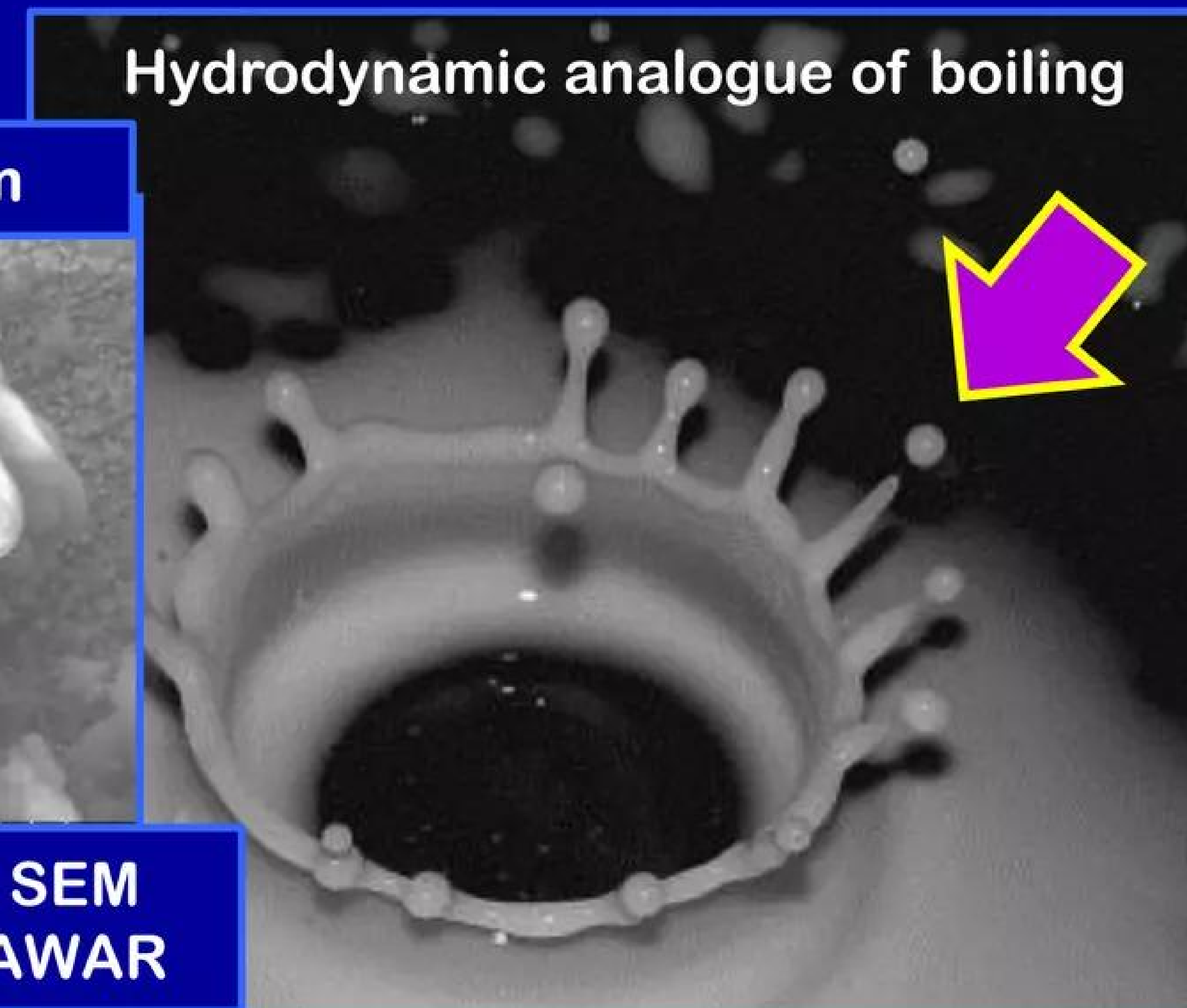


Fig. 1. Phase stability diagram of a liquid metal near the critical point. For fast heating, as obtained during *ns* laser ablation, the melt can be pushed close to critical conditions (superheating), which favors the realization of explosive boiling

Fig. 2. Schematic visualization of the hydrodynamic evolution of a fluid system under and impulse stress (here milk). Note the non-deterministic formation of jets at the sides and their break-up into droplets. From Ref. [58].

Excerpted and quoted from: "Multiplicity and contiguity of ablation mechanisms in laser-assisted analytical micro-sampling" D. Bleiner and A. Bogaerts *Spectrochimica Acta Part B: Atomic Spectroscopy* 61 pp. 421 - 432 (2006)

http://www.sciencedirect.com/science/article/pii/S0584854706000437

Condensed matter LENR-active sites from 2 nm to ~100μ

LENRs create heterogeneous elemental compositions on μ length-scales

Mitsubishi Heavy Industries has observed this effect while transmuting Cs → Pr

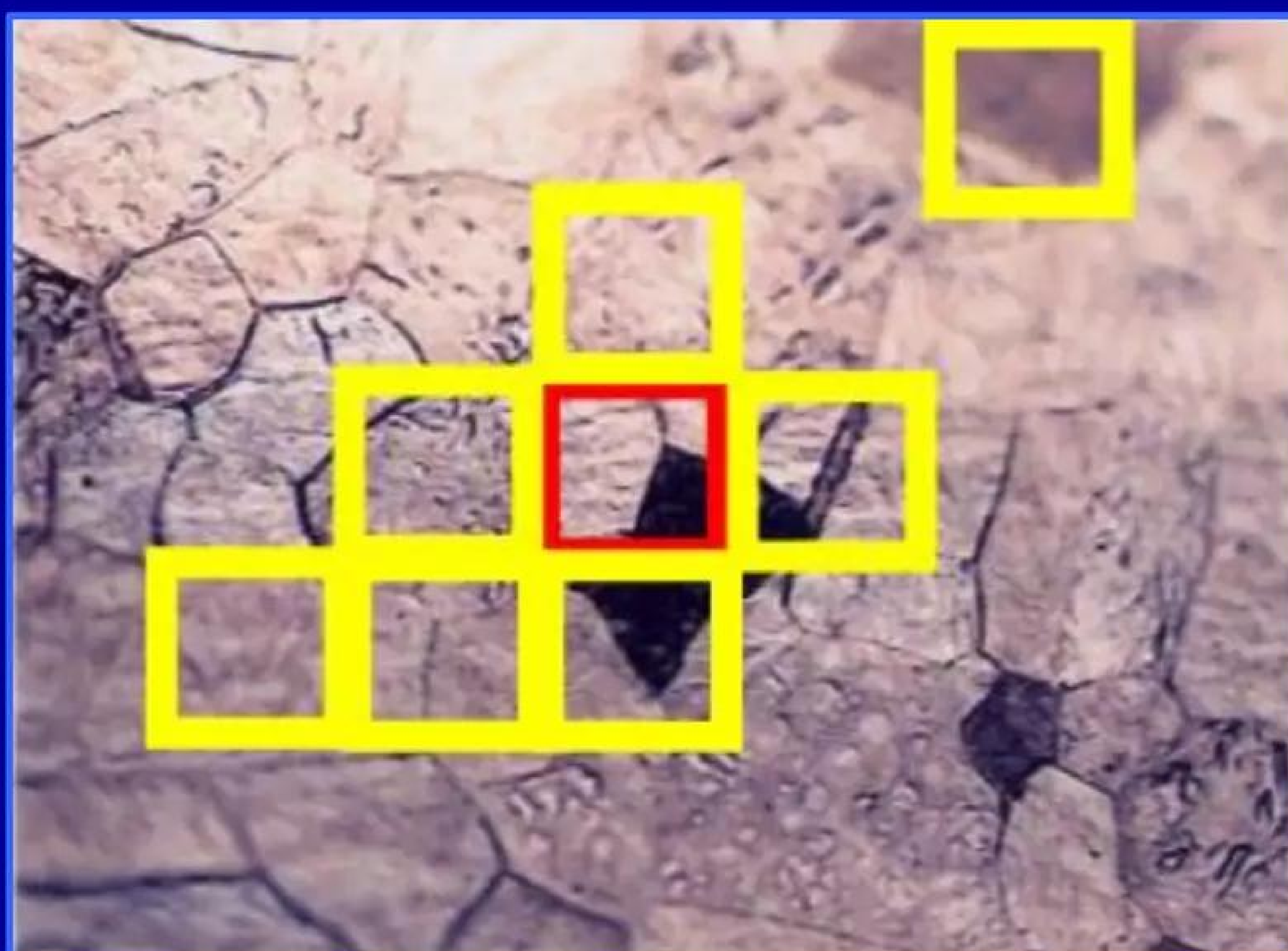
$$^{133}_{55}Cs \rightarrow \, ^{141}_{59}\mathrm{Pr}$$

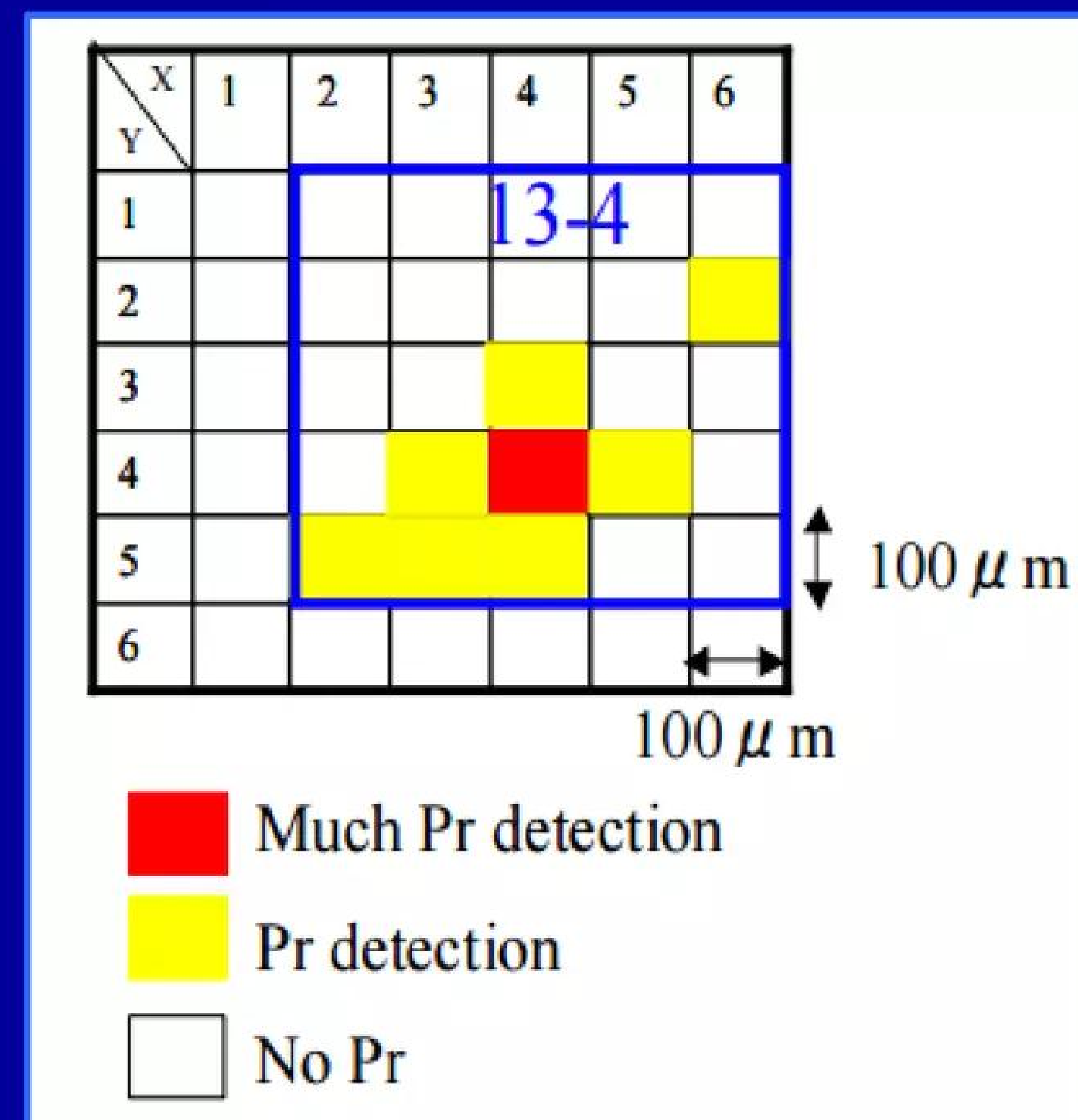
MITSUBISHI HEAVY INDUSTRIES, LTD.
Our Technologies, Your Tomorrow

Implanted Cesium
↓
Praseodymium

Surface of thin-film Pd/oxide heterostructure after experiment

Credit: Mitsubishi Heavy Industries





Credit: Mitsubishi Heavy Industries

See Slide #44 in the following Mitsubishi PowerPoint conference presentation (2013):

http://tinyurl.com/zcr3azt

Toyota also transmuted Cs → Pr using Mitsubishi's method

Apparatus used in experiments and thin-film metal/oxide heterostructure

"Inductively coupled plasma mass spectrometry study on the increase in the amount of Pr atoms for Cs-ion-implanted Pd/CaO multilayer complex with Deuterium permeation"
T. Hioki *et al.*, *Japanese Journal of Applied Physics* 52 pp. 107301 (2013)

http://iopscience.iop.org/1347-4065/52/10R/107301

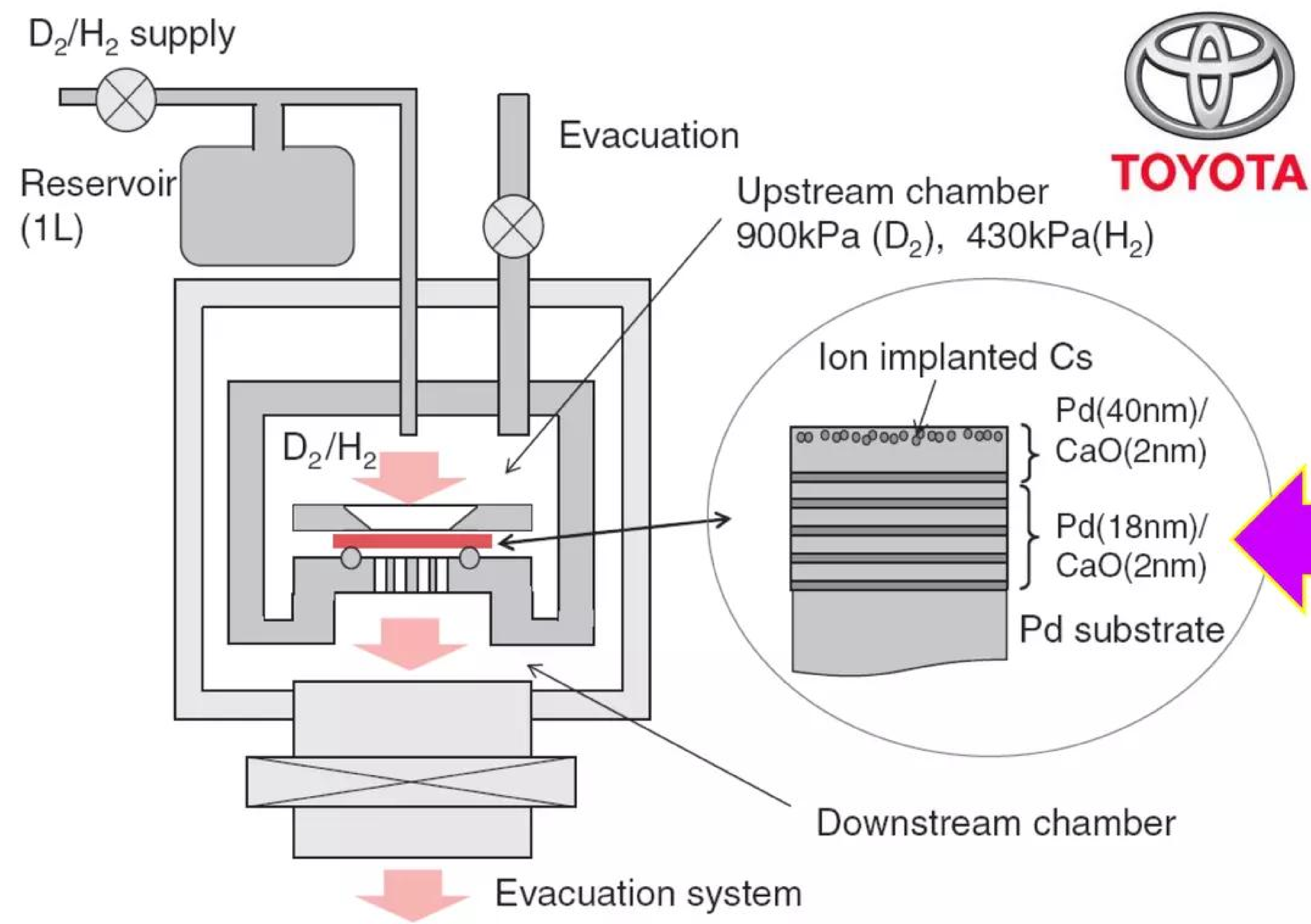


Fig. 1. (Color) Schematics of deuterium (/hydrogen) permeation system and Cs-ion-implanted Pd/CaO multilayer complex.

Figs. 1 and 3 are reproduced from *JJAP* paper by T. Hioki *et al.*

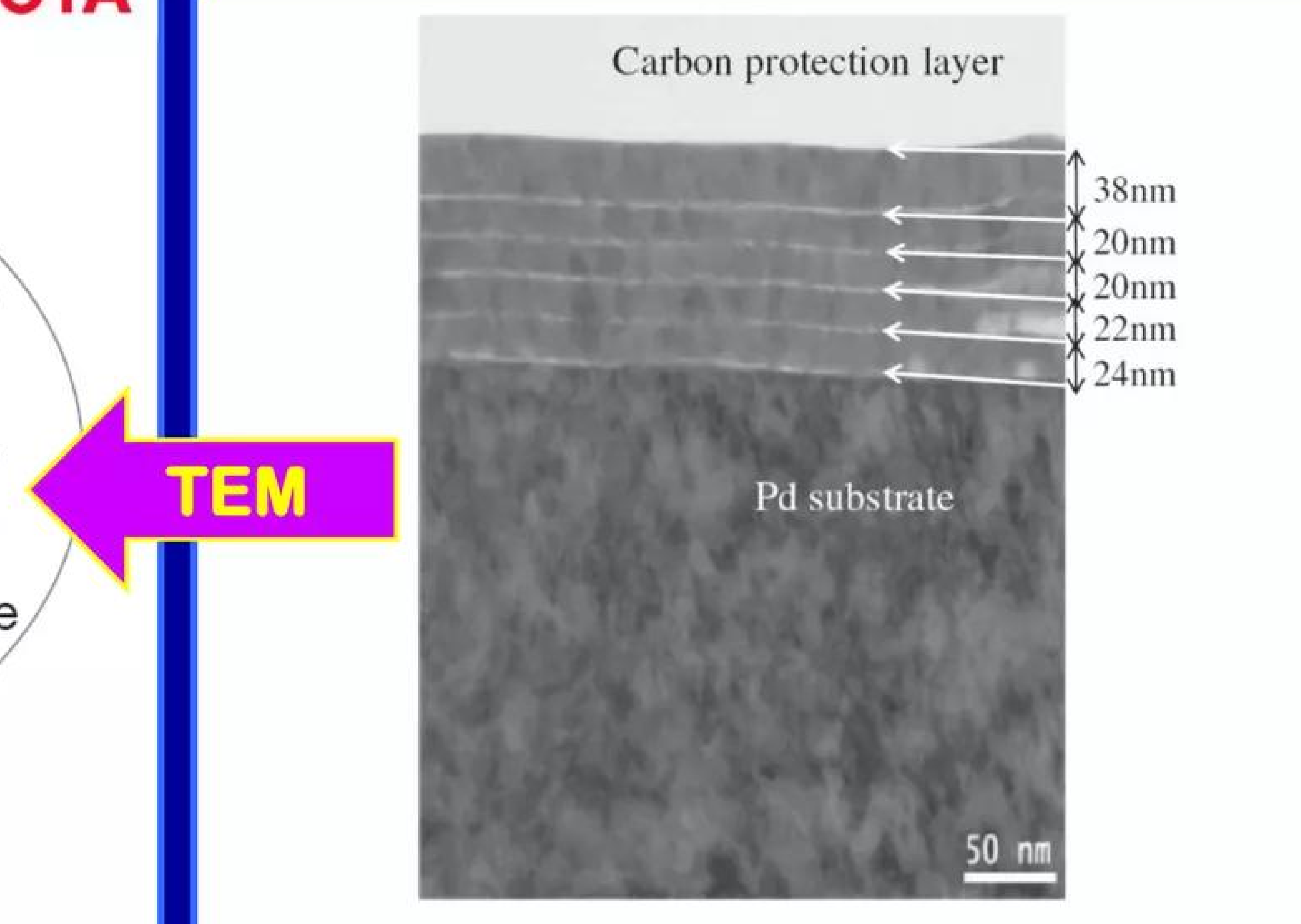


Fig. 3. Cross-sectional TEM view of the Pd/CaO multilayer complex.

Traces of 'fossil' LENR-active sites in meteoritic materials???

Higher isotopic heterogeneity on μ length-scales consistent with LENRs

Many researchers report microscopic "hotspots" using NanoSIMS for analysis

- ✓ Spontaneously formed LENR-active site condensates vary in size. They can range from 2 nanometers (nm) for minimal many-body 'patches' of collectively oscillating protons and electrons (or single host aromatic ring) up to ~100 microns (μm = 10^5 nm)
- ✓ LENR-active sites only survive for estimated 200 - 400 nanoseconds (ns - 10^{-9} sec.) before Q-M condensates are destroyed by local energy releases; thus, duration of neutron production and capture phase is brief. Fortunately, neutron capture is very fast process for ultralow energy neutrons --- on order of picoseconds (ps = 10^{-12} sec.). Importantly, surprising numbers of neutrons can be produced and captured locally during this phase. After sites die, beta decays of short lived, neutron-rich isotopes are the primary lingering nuclear process. As long as input energy is supplied, new LENR-active sites can reform nearby or on top of older sites and repeat the entire neutron production and capture process. Neutron dose histories on surfaces can be complex
- ✓ On fresh, pristine substrates LENR-active sites will rework and roughen surfaces on small length scales. Larger sites create distinctive craters readily imaged with SEMs
- ✓ Depending on what elements are locally present, different substrates or aromatic molecules on which the LENR analogue of the stellar CNO cycle is occurring would be expected to exhibit large, anomalous increases in $\delta\ ^{13}C$, $\delta\ ^{15}N$, $\delta\ ^{18}O$, and $\delta\ ^{2}H$. While Deuterium (^2H) is mobile and easily migrates away from sites, heavier elements would tend to stay put and create localized "hotspots" with spatially correlated anomalies

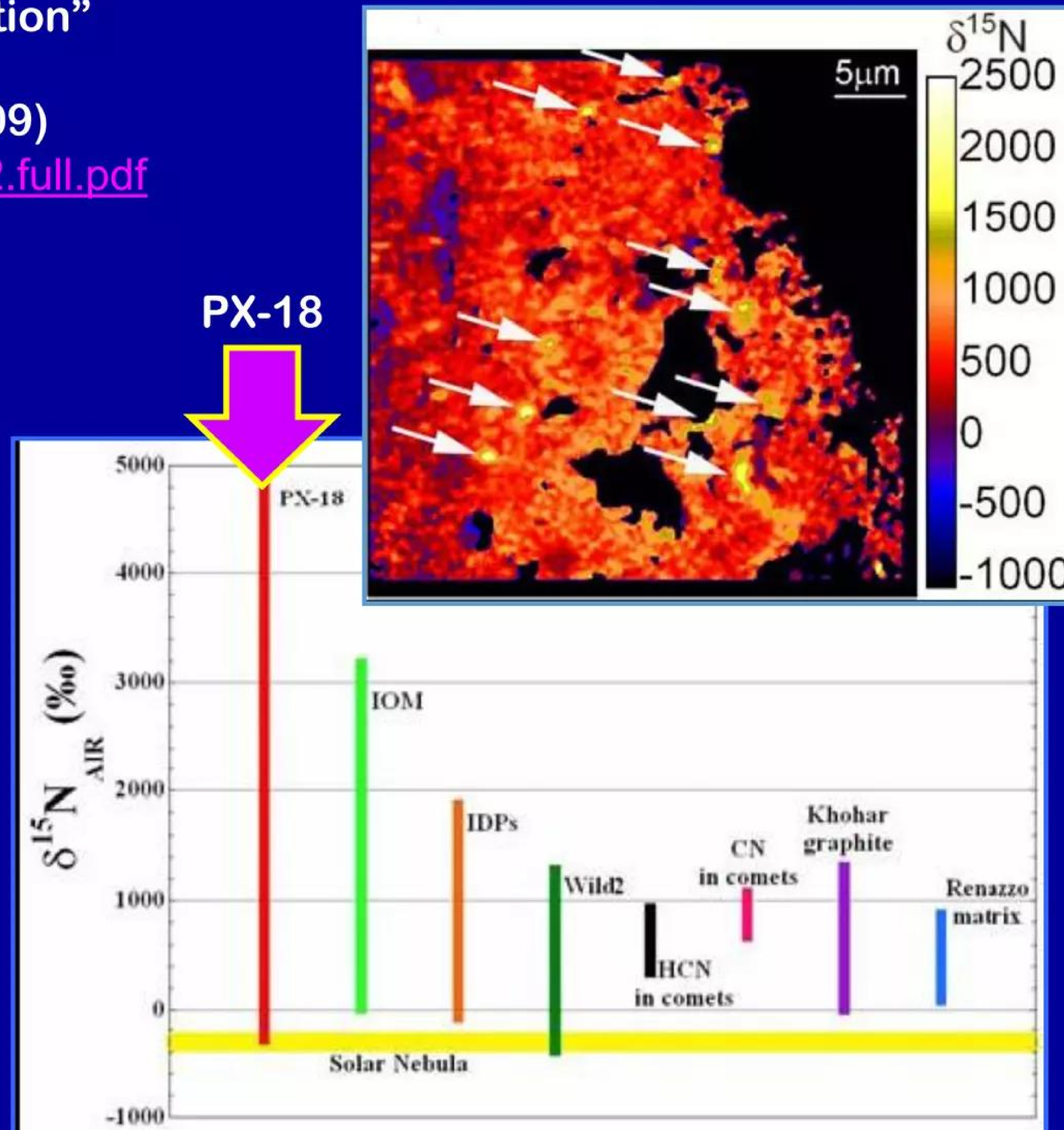
LENRs can create large increases in $\delta\ ^{13}C$, $\delta\ ^{15}N$, $\delta\ ^{18}O$, $\delta\ ^{2}H$

NanoSIMS shows huge local ^{15}N increases concentrated in tiny hotspots

"Pristine extraterrestrial material with unprecedented nitrogen isotopic variation"
G. Briani *et al.*
***PNAS* 10.1073 – pnas 0901545106 (2009)**
http://www.pnas.org/content/106/26/10522.full.pdf

" … extreme continuum of N isotopic variation is present in this xenolith: from very light N isotopic composition ($\delta\ ^{15}N_{AIR}$ -310 ± 20‰), similar to that inferred for the solar nebula, to the heaviest ratios measured in any solar system material ($\delta\ ^{15}N_{AIR}$ 4,900 ± 300‰). At the same time, its hydrogen and carbon isotopic compositions exhibit very little variation. This object poses serious challenges for existing models for the origin of light element isotopic anomalies."

PX-18: Nitrogen $\delta^{15}N$ hotspots



LENRs resemble r-/s-processes; mimic supernova products

Huge *μ*-scale isotopic variance; spatially correlated hotspots: ^{15}N and ^{18}O

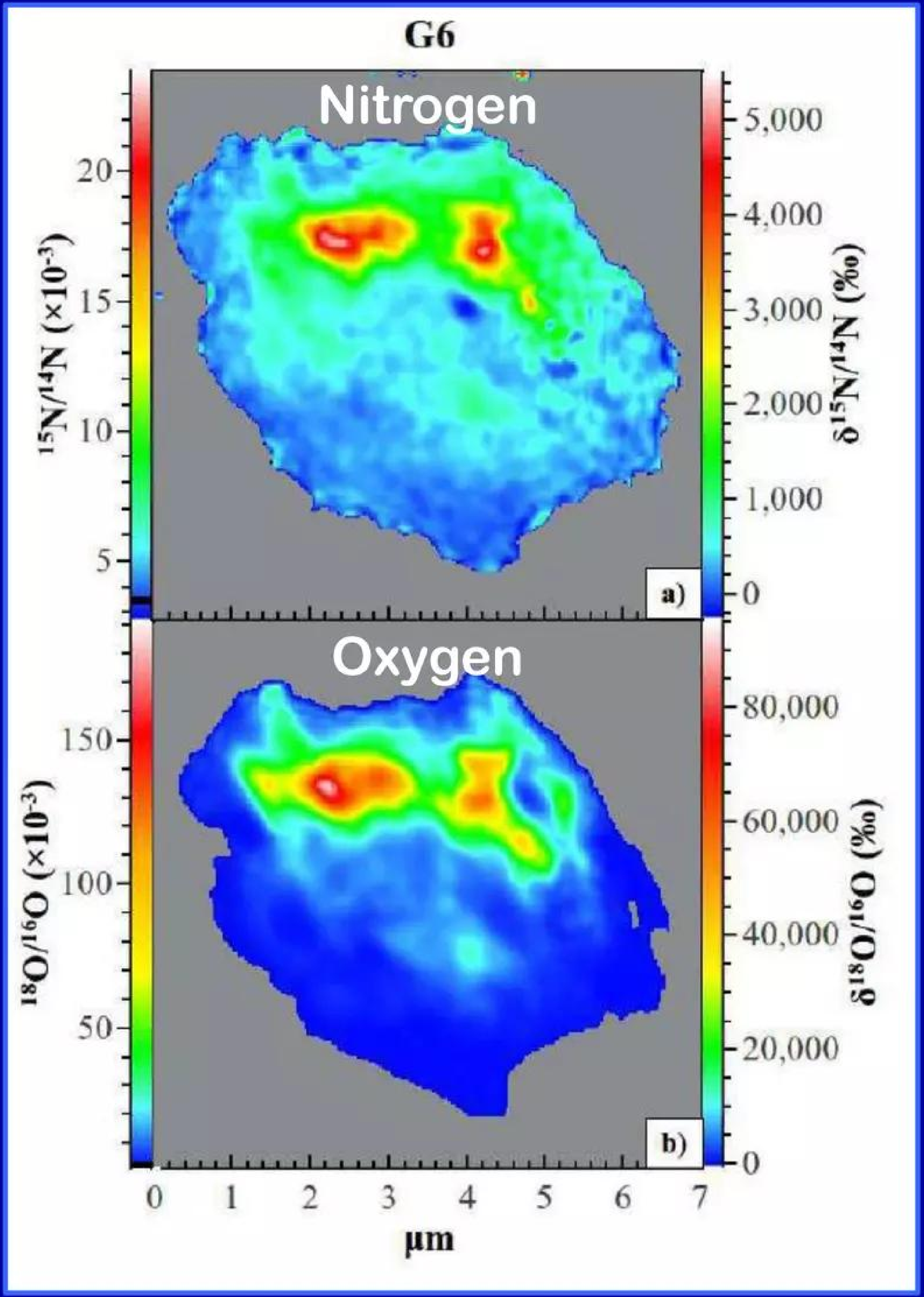
NanoSIMS was used to collect this data

"C, N, and O isotopic heterogeneities in low-density supernova graphite grains from Orgueil" E. Groopman *et al.* *The Astrophysical Journal Letters* 754 (2012)

http://arxiv.org/pdf/1405.7557v1.pdf

Fig. 1. "False-color isotope images of the surface of G6. Images are scaled in absolute ratios (left) and δ-values (right) where $\delta^{i}X = \delta^{i}X / {}^{j}\delta X = 1000 \times (({}^{i}X / {}^{j}X)_{sample} / ({}^{i}X / {}^{j}X)_{standard} - 1)$ and ${}^{j}X$ is the major isotope ^{14}N or ^{16}O. Black bars on left indicate terrestrial isotopic ratios ($^{15}N / {}^{14}N_{terrestrial} \approx 0.004$; $^{18}O / {}^{16}O_{terrestrial} \approx 0.002$). a) $\delta\, ^{15}N$ isotope image. Deviations from terrestrial range up to 6,400 ‰ ($^{15}N / {}^{14}N = 0.03$, $^{14}N / {}^{15}N = 37$). b) $\delta\, ^{18}O$ isotope image. Deviations from terrestrial range up to 98,000 ‰ ($^{18}O / {}^{16}O = 0.20$, $^{16}O / {}^{18}O = 5$). There is a good spatial correlation between the hotspots in $\delta\, ^{18}O$ and $\delta\, ^{15}N$."

Figure 1

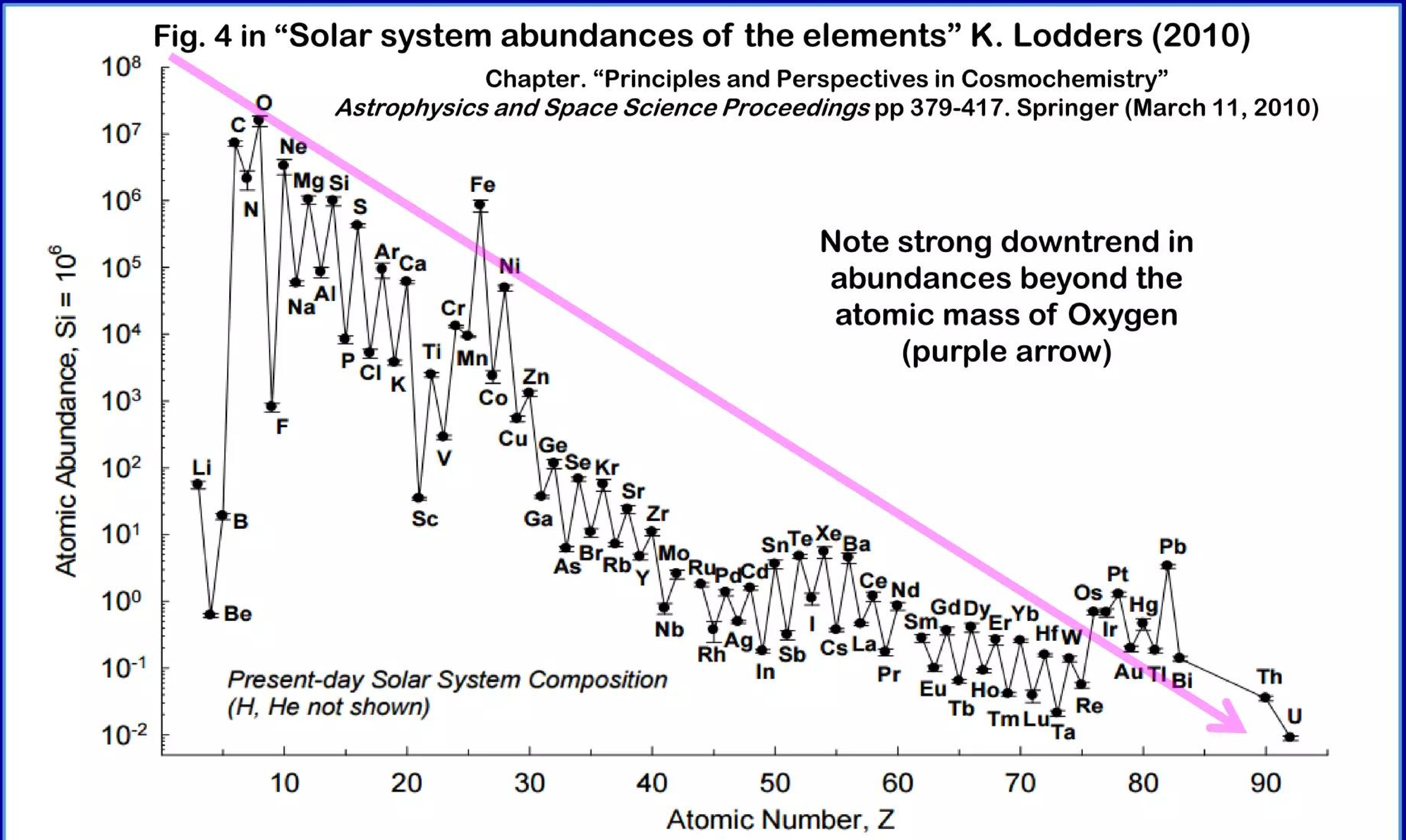


Electroweak processes help explain white dwarf "pollution"

- ✓ As shown in previous slides, a large body of published data collected in earthbound laboratory experiments and NanoSIMS studies of meteoritic materials clearly reveals that elements and isotopic compositions of condensed matter can be surprisingly heterogeneous and vary enormously on nm - μ length-scales. Importantly, LENRs in condensed matter are intrinsically microscopic phenomena as a result of size limits on Q-M condensates that can form spontaneously in LENR-active sites. Furthermore, chemical and nuclear processes can interoperate on surfaces or at interfaces. That being the case, unraveling and fully understanding the chemical and nucleosynthetic history of materials on cm length-scales can be a fiendishly complex, difficult task
- ✓ Now consider an even bigger challenge of understanding details of chemonuclear evolution of decidedly macroscopic white dwarf stars the size of Earth or vastly larger agglomerations of materials found in circumstellar accretion disks that may be distributed across length-scales measured in astronomical units. Those caveats stated, some general statements can be made about a possible role for LENRs in helping Nature shape elemental abundances in "metal polluted" white dwarf stars as well as extreme isotopic shifts and elemental anomalies seen in directly accessible meteoritic and cometary materials that have arrived to Earth from outer space
- ✓ Many-body collective electroweak neutron production can potentially occur in: (1) plasma-filled magnetic flux tubes that may form in white dwarf atmospheres; and/or (2) on surfaces of Hydrogen-rich dust grains, either while they are peacefully orbiting in circumstellar disks being irradiated by starlight or during the process of getting trapped in a gravitational field gradient and gradually being sucked into a star

Relative abundances of chemical elements in solar system

Note steady decrease in abundance beyond the atomic mass of Oxygen

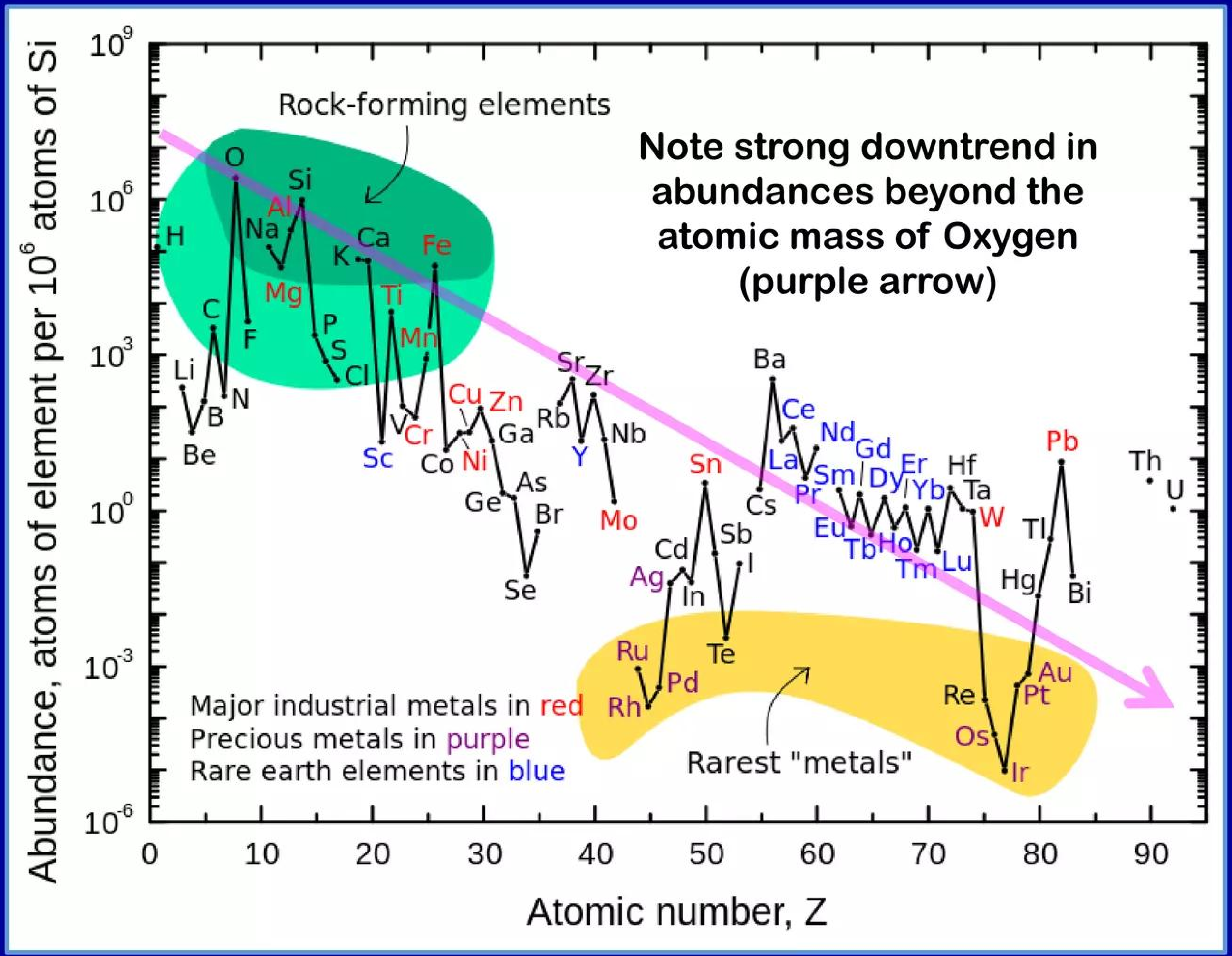


http://arxiv.org/ftp/arxiv/papers/1010/1010.2746.pdf

Relative abundances of chemical elements in Earth's crust

Many of these elements were verifiably produced in LENR experiments

Earth considered a typical rocky planet that accreted in Sun's circumstellar disk



Credit: "Elemental abundances" by Gordon B. Haxel, Sara Boore, and Susan Mayfield from USGS
Vectorized by User: michbich Adapted by Lattice

Terrestrial experiments show LENRs can approximate stars

Neutron production rates are less than supernovas but can exceed stars

- ✓ Input energy required for many-body collective electroweak neutron production can come directly from magnetic fields found inside plasma-filled flux tubes. It can also come from incoherent photons radiating from stars. Amazingly, it might even be provided by huge electrical currents that some scientists believe could occur in nebular lightning discharges (see "Can lightning produce significant levels of mass-independent Oxygen isotopic fractionation in nebular dust?", J. Nuth III *et al.*, *Meteoritics and Planetary Science* 47 pp. 2056 - 2069, 2012)
- ✓ On dust grains, episodic local heating from LENRs can break molecular chemical bonds as well as greatly accelerate rates of chemical reactions. Over time this can influence chemical evolution of space dust and subsequent protoplanetary materials, an infinitesimal % of which will end-up in measurable meteoritics
- ✓ All other things being equal, rates of collective electroweak neutron production are directly dependent on local concentrations of electron and proton reactants and on total amount of input energy injected into LENR nucleosynthetic systems
- ✓ In terrestrial laboratory experiments, inferred neutron production rates range from several per cm^2/sec up to as much as 10^{12} - 10^{14} cm^2/sec in well-performing electrochemical cells driven with moderate DC currents. Certain nanosecond rise-time, pulsed high-current electric discharge experiments may have briefly reached rates of 10^{18} - 10^{20} neutrons cm^2/sec. By comparison, astrophysicists estimate neutron production rates to be ~ 10^5 - 10^{11} cm^2/sec during Helium burning in AGB red giant stars and on the order of ~ 10^{22} - 10^{25} in supernovas

Neutron production rates in accretion disks & white dwarfs

- ✓ While no hard observational data is presently available, one could reasonably speculate that many-body collective electroweak neutron production rates could be quite substantial in plasma-filled magnetic flux tubes on white dwarfs. This is especially true for close-binary MCVs which combine enormously high surface magnetic fields with spatially extended flux tubes that transport plasma from a companion star or stellar-mass black hole to one of the magnetic poles on a white dwarf (e.g., so-called "polars")
- ✓ In the case of Hydrogen-rich dust grains out in circumstellar accretion disks simply irradiated with starlight, given a much smaller amount of available impinging input energy one could expect that LENR neutron production rates might be extremely low, likely much less than seen in Mitsubishi's early Deuterium permeation experiments (Iwamura et al., *JJAP* 2002). However, rates on dust grains could increase significantly during the process of falling into stars prior to reaching sublimation zones where they would lose integrity as condensed matter particles
- ✓ If nebular lightning really occurs in dusty accretion disks then electroweak neutron production rates could be quite high in and around a lightning bolt's dust-filled ionization channel --- perhaps ~10^{10} - 10^{20} cm^2/sec. This is because these bolts would be huge (est. length = 100 km, dia. = 70 m per Nuth *et al.,* 2012) and would provide huge amounts of input energy to both accelerate charged particles in the plasma proper as well as drive condensed matter LENRs on surfaces of dust grains embedded in channel plasmas

Neutron capture cross-sections at thermal energies

Stable isotope	Cross-section (barns)
^{1}H	.332600
^{2}H	.000519
^{3}He	5.3 x 10^3
^{4}He *	.860000
^{12}C	.003530
^{13}C	.001370
^{14}N	1.910000
^{15}N	.000196
^{16}O	.000100
^{17}O	.236000
^{18}O	.000160

MCV white dwarf has anomalously high Nitrogen abundance

LENRs on PAH aromatic rings depletes ring Carbons by creating Nitrogen

Benzene
C_6H_6

IRFU
Institute for Research into the Fundamental Laws of the Universe

Phenanthrene - PAH
$C_{14}H_{10}$

"Nitrogen overabundance in cataclysmic couples – a new source of chemical elements"
http://irfu.cea.fr/Sap/en/Phocea/Vie_des_labos/Ast/ast_actu.php?id_ast=1313

"The CNO problem in magnetic cataclysmic variables", J. Bonnet-Bidaud & M. Mouchet in "Magnetic Cataclysmic Variables", IAU Col. 190, Eds.: Cropper & Vrielmann (2003)
http://arxiv.org/pdf/astro-ph/0302158v1.pdf

- ✓ Discovered MCV white dwarf with huge 25x cosmic overabundance of Nitrogen and underabundances of Carbon (1/8 of cosmic) and Oxygen (2x lower) in its atmosphere; seemed as though a CNO cycle was now or had somehow been operating on the star
- ✓ Were unable to explain data with nova or "quiet nova" event on star in which stellar CNO cycle reactions had recently occurred (no observational evidence for hypothesis)
- ✓ Ended by speculating that these elemental abundance anomalies had really been created on the binary star's other companion and transported to the MCV WD via the connecting flux tube. Remarked that this new discovery could, "… lead to a significant revision of the origin of CNO in the galaxy." Were also suspicious about accretion disk
- ✓ While their explanation is quite plausible, could also be explained by accretion of dust grains comprised of mixed metal oxides with rich admixtures of bound PAH molecules on their surfaces. LENR CNO analogue on PAHs (C_nH_n) would deplete C and enrich N

GALEX J1717: weird upward-trending abundance anomalies

Neutron captures on pure Carbon could create the observed abundances

"Heavy metals in a light white dwarf: Abundances of the metal-rich, extremely low-mass GALEX J1717+6757" [see next slide]
J. Hermes *et al.*, *Mon. Not. R. Astron.* 444 pp. 1674 - 1682 (2014)
http://www.nhn.ou.edu/~alexg/publications/Hermes_2014_MNRAS_444_1674.pdf

- ✓ Extremely low mass (ELM), close binary, Hydrogen-rich (He 5% solar), heavily polluted WD star's discovery first reported in 2011 (S. Vennes *et al.*, *Apj Lett.*); faint companion star is also a WD which is more massive (no spectral signatures of it were detectable). Spectroscopically observed reported abundances for this star presented on next slide; note weird *upward slope* of abundances relative to solar values (compare to earlier slide)
- ✓ Studied this ELM star because gravitational field is low enough for radiative levitation to be able to lift certain elements out of near-surface materials (presumably comprising mostly Carbon with an unknown amount of Oxygen and perhaps some other elements) into WD J1717's atmosphere where they can then be detected with satellite-based spectroscopy
- ✓ Some abundances agreed with values predicted by radiative levitation calculations but there were anomalous abundances for certain elements, notably Carbon which had value 300x less than expected whereas Calcium abundance was vastly higher than expected
- ✓ Concluded that accretion was absent for this star and that levitation cannot explain data
- ✓ Assume that Carbon was levitated as predicted: J1717's abundance pattern is ~ consistent with neutron captures on pure Carbon inside plasma-filled magnetic flux tubes located somewhere on J1717. W-L-S collective electroweak process in tubes creates the neutrons

GALEX J1717 + 6757 does not appear to have accretion disk

Abundance uptrend is consistent with neutron captures on pure Carbon

Figure 5. Element abundances in GALEX J1717+6757 (adapted by Lattice)

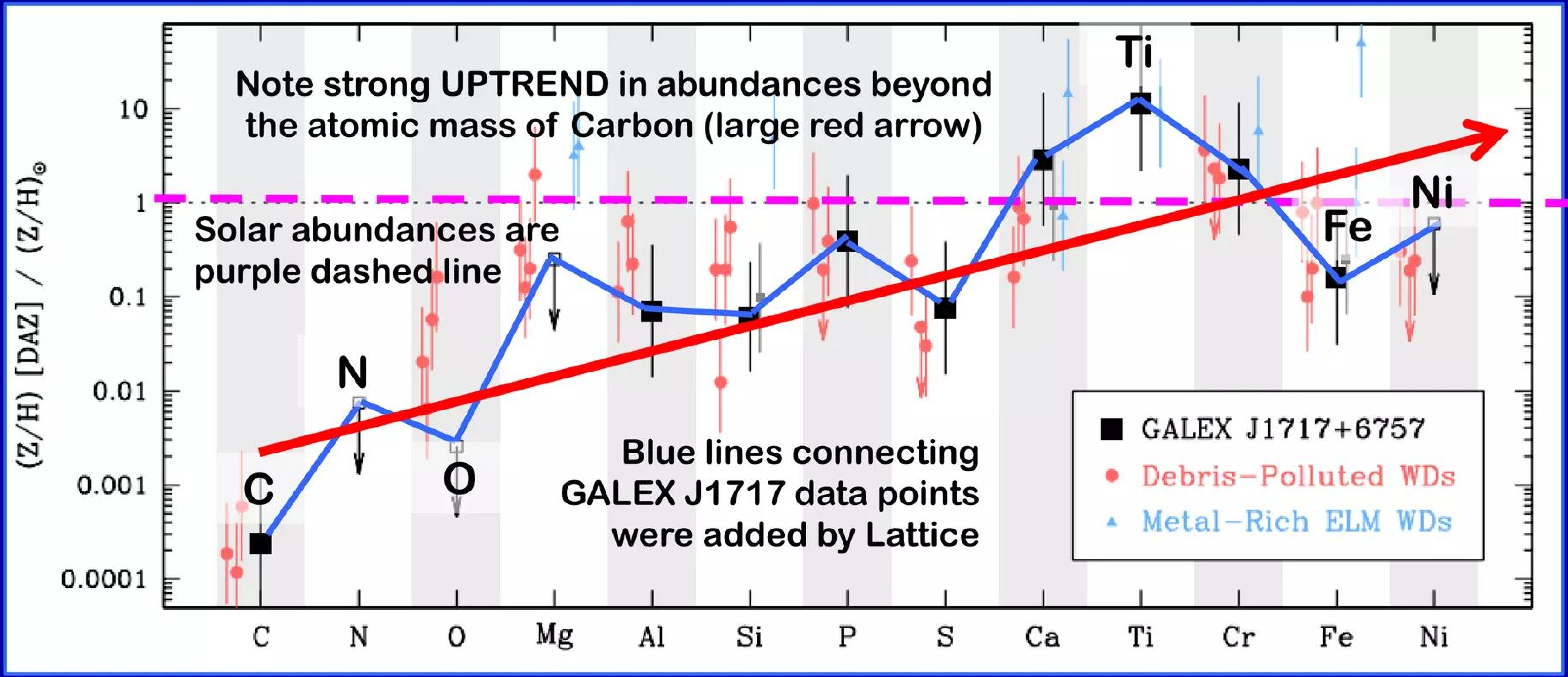


Figure 5. "Element abundances in GALEX J1717+6757, detailed in Table 1. Our measured abundances are displayed as large black squares relative to solar (Asplund *et al.* 2009), marked by the dotted line, and upper limits are shown as open black squares. The abundance determinations from the optical spectrum of GALEX J1717+6757 by Vennes et al. (2011) are included as smaller dark gray squares. Note that this figure spans more than six orders of magnitude. We include, as light red points left of our target, abundances from four average-mass WDs that have debris disks and are polluted from exo-terrestrial planetesimals; these WDs were analysed in an identical way by Gansicke *et al.* (2012). We also include abundances for the metal-rich low-mass WDs PSR J1816+4510 (Kaplan et al. 2013) and SDSS J0745+1949 (Gianninas et al. 2014) as light blue points."

LENR CNO cycle could be used in power generation on Earth

Convert aromatic fractions in oil, coal, natural gas into green LENR fuels

Development risks can be reasonable thanks to Widom-Larsen and nanotech

Guided by physics of the Widom-Larsen theory, an opportunity to commercialize LENRs as truly green CO_2-free nuclear energy source has been enabled by a unique juxtaposition of very recent parallel advances in certain very vibrant areas of nanotechnology (esp. plasmonics), quantum entanglement, new innovations in nanoparticle fabrication techniques, as well as an array of new discoveries in advanced materials science.

Visualization of plasmon electric fields on surface

Fossil fuels could be converted into green LENR fuels

Breakthroughs in physics and nanotechnology make this possible

Bitumen, heavy oil, and coal may be much more valuable as CO_2-free LENR fuels

In 2009 Larsen discovered that aromatic molecules can potentially be extracted and processed to be converted into green LENR fuels in which there would be no hard radiation emissions, no production of any long-lived radioactive wastes or emission of gaseous CO_2 into the atmosphere; would instead release **> 5,000 times more thermal energy versus combustion of Carbon-based molecules with Oxygen**

All of these fossil hydrocarbons contain aromatic ring molecules that can be extracted

Canadian bitumen

Heavy viscous oil

Anthracite coal

Fossil Carbon could be transmuted rather than combusted

Heavy oil and coal could be processed to produce CO_2-free LENR fuels

Carbon atoms found on aromatic rings good fuel for radiation-free transmutation

Radiation-free LENR transmutation

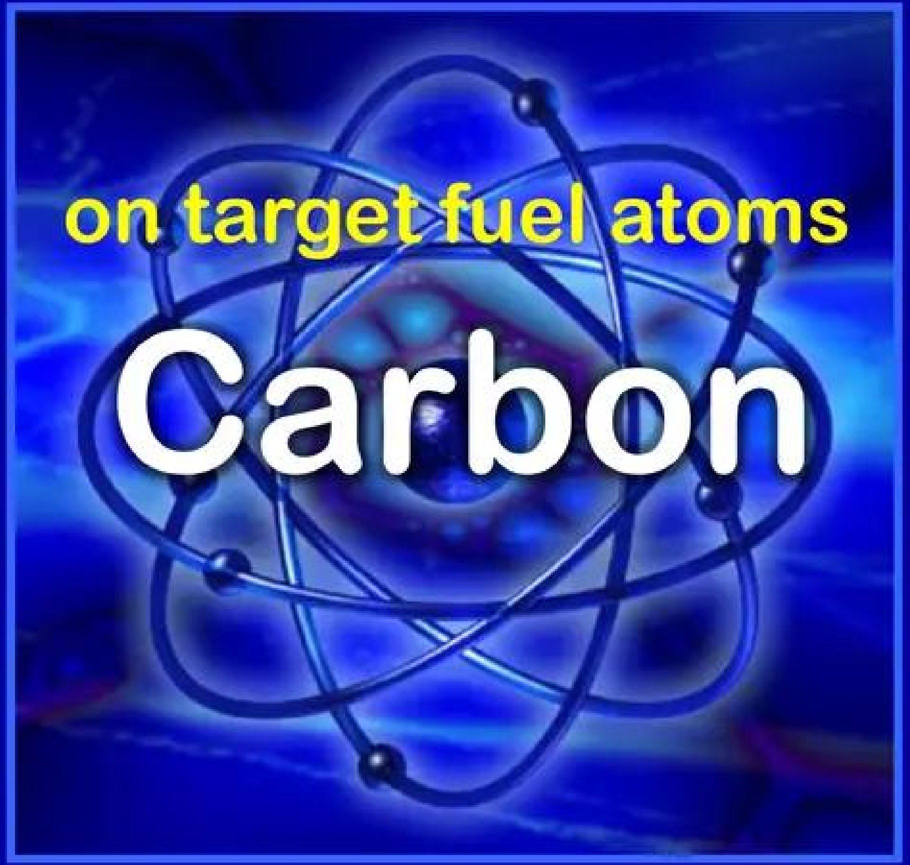
Neutrons + target fuel atoms → heavier elements + decay products + heat

Catalytic neutron ‘match’

capture

+

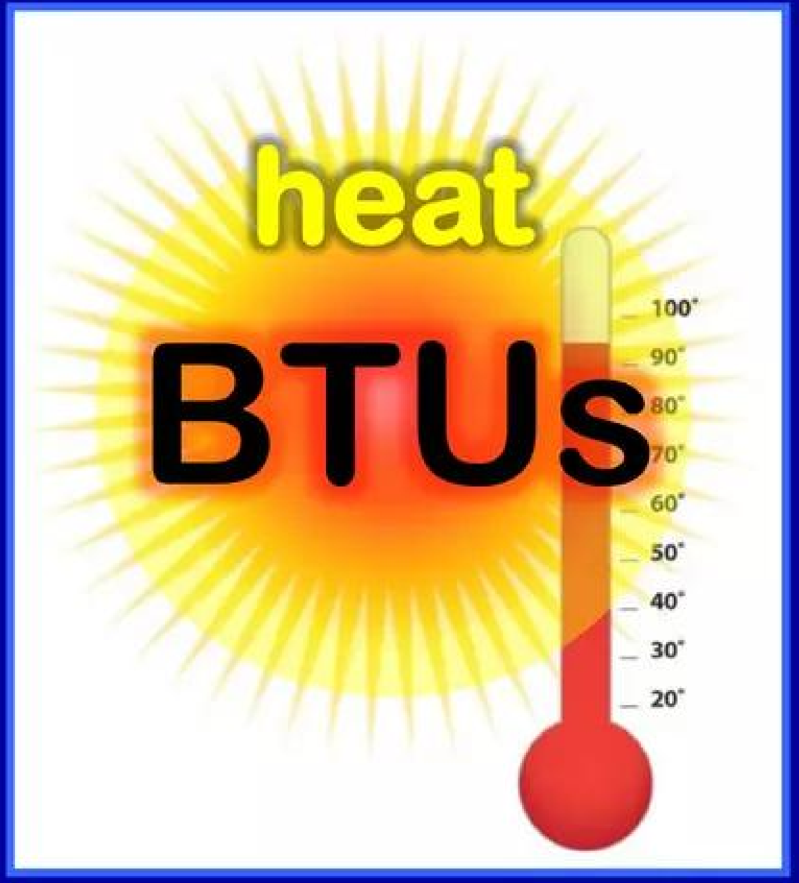
Neutrons are readily absorbed by LENR fuels such as inexpensive Nickel, Titanium, Lithium, or Carbon atoms



produces

→

Direct conversion of neutron capture and decay-related gammas to IR and beta/alpha particles create heat



Process does not emit any deadly radiation or produce troublesome radwastes

Many moieties contain or are convertible into aromatics

LENR fuels can be created from many different types of Carbon sources

Base feedstock → Aromatic molecules → Nanoparticulate fuels

Contain aromatic molecules

Examples:

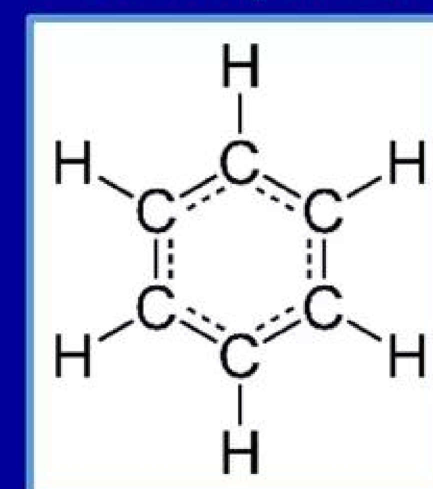
- Heavy oils and natural bitumen — Extract →
- Coal — Extract →
- Lignin from renewable biomass — Digest →

Chemical process

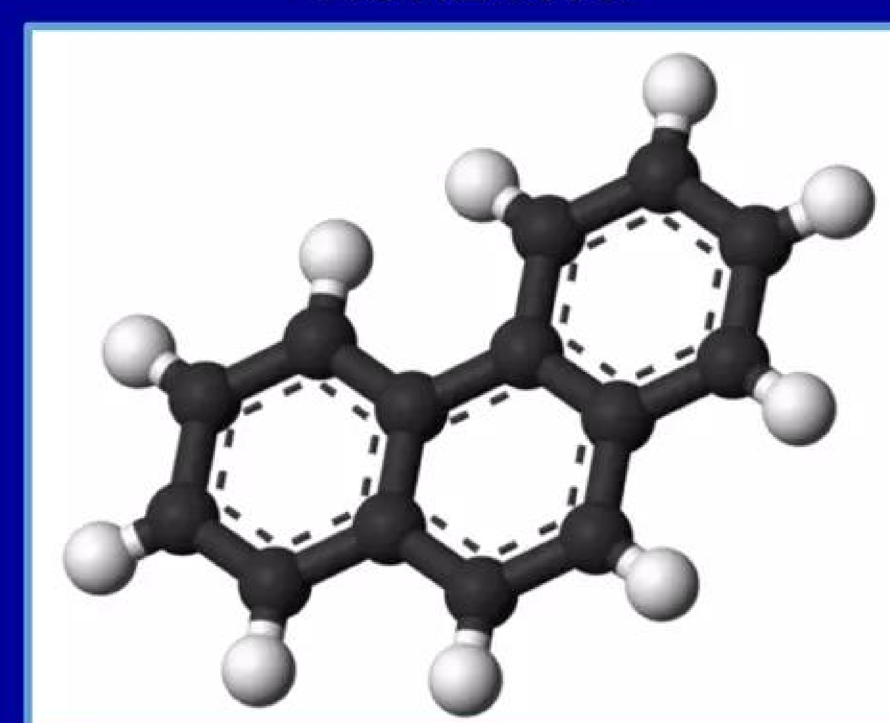
- CH_4 natural gas — Mo catalyst / LNG →
- CO_2 → C nanofibers — Processing ↑

Variety of simple and complex aromatic molecules

Examples:



Benzene



Phenanthrene

Enormous gain in energy density makes processing conversions $$$ economic

Chemical processing

Process into

plus nanotech

Green CO_2-free LENR fuels

5,000x greater energy density

Bottom line: just about any Carbon-based moiety can be converted into aromatic ring-structure molecules using a chemical process

Hyperlinked references

Many-body collective effects in condensed matter and magnetic plasmas

Condensed matter

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$\text{Energy}_{\text{B-field}} \rightarrow e^- + p^+ \rightarrow lepton + X$

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Condensed matter

$\text{Energy}_{\text{B-field}} \rightarrow e^- + p^+ \rightarrow lepton + X$

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Lattice's Index provides comprehensive guide to info about W-L-S theory

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